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The front cover shows a Hortonsphere for storing liquefied gas at the British Petroleum Company's Kent Oil Refinery.

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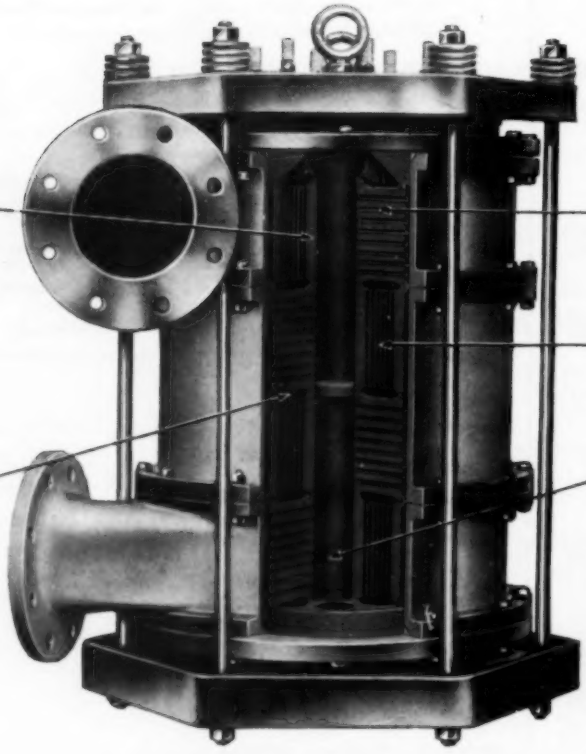

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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

By-ways of Scientific Policy

BY 1970, we should have an output of about 22,500 scientists and technologists a year giving a small margin over a target of 20,000. This estimate by the Advisory Council of Science Policy — representing a favourable feature of national scientific development—together with their criticisms of the lack of teachers and our neglect of Russian, received publicity in the daily press. Less noticed was the quotation with approval from a Royal Society review of our national research, in which attention is drawn to the danger of neglecting the "urgent needs" of biological science. The immediate context of the remark is in relation to university research but it is likely to be true in a wider sense. Strangely, the re-publication of this comment almost coincided with the news that the research section of the microbiology group at the National Chemical Laboratory is to be disbanded. At present this section is studying sulphate-reducing bacteria, carrying out pilot-plant trials (in conjunction with the London County Council) on sulphide production from raw sewage sludge* and working on oxidation of aromatic compounds either for process purposes or to minimise nuisance. There is also work in progress on the biochemical mechanism of methane production by anærobic fermentation of organic wastes such as sewage sludge. A project not yet started is that for up-grading non-caking coals so that they will produce good coke.

The National Collection of Industrial Bacteria is held at the same laboratory and last year issued 1508 cultures —403 of them to industrial establishments in the U.K. For the first 11 months of 1958 the total issue had risen to 1,600. This collection supplies organisms for the assay of antibiotics, vitamins and amino-acids, and others for carrying out biochemical reactions. The proposal—as part of the same reorganisation—to transfer this collection from a London suburb to Torry in Scotland would not seem to be a particularly useful contribution to remedying neglect of biological science.

* See BRITISH CHEMICAL ENGINEERING, 1956, 1, 347.

Designing for Mechanically-aided Heat Transfer

FOR cases where heat transfer accompanying a phase change is aided by the use of moving mechanical parts, D. Q. KERN and H. J. KARAKAS have recently provided a design analysis. This type of processing is often required for dealing with changes of phase involving very viscous or foaming materials such as polymeric solutions or suspensions, slurries and pastes where viscosities of 100,000 centipoises are not unusual. Based on combining theoretical principles of heat and mass transfer, hydrodynamics and rheology, relationships have been established involving the heat-transfer co-efficient, power requirement, throughput and holdup as functions of equipment geometry and operation and the fluid properties. The treatment covers viscous, Newtonian and non-Newtonian liquids including those with a high-temperature coefficient for the viscosity. Cases considered are for rotors with fixed blades and those with hydrodynamic blades. The latter have freedom of movement on a secondary pivot bearing and take up a position determined by the balance between centrifugal and hydrodynamic forces. A worked example concludes the paper (Preprint 17) which was presented at the Second National Heat Transfer Conference and preprinted by the American Institute of Chemical Engineers.

Light on Heat

BLENDING description, theoretical discussion and tabulation of data, the latest monograph* published by the Royal Institute of Chemistry presents a large amount of information on thermochemistry without becoming a mere catalogue. In it DR. H. A. SKINNER discusses changes in energy associated with a number of chemical processes. They include decomposition, combustion, hydrogenation, halogenation and hydro-halogenation, hydrolysis and polymerisation. Most of this material is based on calorimetry but measurement of bond dissociation energies provides the only practicable means of determining the heat of formation of radicals. In one section the sources of this information are critically considered and a table of "best" values given. For the homologous series R-X values are given for the constants in the general equation for the heat of formation in the gaseous state at 25°C.

$$\triangle H_f = A + Bn + \triangle$$

In this n is the number of carbon atoms in the radical $R = C_nH_{2n+1}$ and X may be $-CH_3$, $-C_2H_3$, $-C_2H$, $-C_6H_5$ or $-C_6H_{11}$. $\triangle$ is a 'deviation term'.

* "Modern Aspects of Thermochemistry." 52 pp., 6s.

Interchangeability of Engineering Equipment in the Inch and Metric Systems

YOU may well hear more about "functional interchangeability" and it would be useful to open by quoting its official definition*: "functional interchangeability is achieved when those characteristics of the finished product which affect its operation have been standardised to the necessary degree of accuracy." This frequently includes characteristics other than linear dimensions, but in most cases the complete standardisation of all characteristics is neither possible nor necessary. Dimensional interchangeability is a partial aspect of functional interchangeability and is achieved when the linear dimensions of two finished products are sufficiently close to one another to ensure interchangeable replacement.

The Engineering Equipment Users Association have now issued a statement to publicise the suggestion of using "corresponding values" to overcome the difficulties caused

by each country naturally prefering to standardise in terms of their own set of units in rounded numbers. This system consists in expressing a dimension both in inches and in metric units to a sufficient degree of accuracy to ensure practicable interchangeability. Thus, if only approximate accuracy is required, reasonably round numbers can be used in both systems. For example, for the length of a tube, 7 metres can be taken to "correspond" to 23 ft; similarly 0.176 in. (7 s.w.g.) is sufficiently close to 4.5 mm. to provide interchangeability where pipe thickness is concerned. These views have the full support of B.S.I. who are urging that as a first step inch equivalents should always be listed in international recommendations side-by-side with their metric opposite numbers. Neither the British Chemical Plant Manufacturers Association nor the Association of British Chemical Manufacturers were involved in the discussions leading up to the issue of this statement but these decisions will evidently affect them as much as other users or sellers of engineering equipment.

* Adopted by the Standing Committee on Scientific Principles of Standardisation, of the International Organisation for Standardisation.

Diffusion and Chemical Kinetics

QUINTESSENCE of the specialised field of study of the chemical engineer is most clearly shown when dealing with a process in which a chemical reaction occurs at the same time that mass exchange takes place. Processes of this kind—involving physical diffusion and chemical reaction rates simultaneously—include gas absorption with reaction, heterogeneous catalysis, mixing and reaction, rapid combustion reaction and many others. The subject is critically reviewed in a duplicated monograph* by ROBERT L. PIGFORD in generalised terms, without special reference to specific applications. Statements of the penetration theory and its extension into the theory of the surface replacement model lead into studies first of kinetics of simultaneous diffusion and simple chemical reaction, then of more complex cases. This unusual publication also includes reports of experimental studies, both of gas absorption in water accompanied by first-order irreversible chemical reaction and of bimolecular reactions. Examples of the former are absorption of carbon dioxide in aqueous ammonia solution or of nitrogen dioxide in water. The latter include absorption of chlorine in reaction liquids and of carbon dioxide in aqueous ethanolamine solution.

* "Diffusion and Chemical Kinetics." Department of Chemical Engineering. University of Delaware. 1958.

Liquid Reagents for Removing Hydrogen Sulphide

AT a more immediately practical level similar studies have been involved in developing methods of using liquid reagents for the final removal of hydrogen sulphide from fuel gases. In a paper to the Autumn Research Meeting of the Institution of Gas Engineers, W. B. S. NEWLING concluded that in the liquid phase the rate of absorption of hydrogen sulphide by alkaline zinc reagents which he had developed is controlled almost exclusively by chemical reactions. Theme of the paper was that most oxide purifiers could be operated at very much increased throughputs of gas, if all elements of good practice were brought into play. Thus, a deliberate policy of increased loading need involve little risk except the presence of a small slip of hydrogen sulphide at the purifier outlet; this could be removed by washing with an alkaline zinc reagent. MR. NEWLING considered that cheaper purification should be possible if the system of oxide purifiers alone were to be replaced by the combination of oxide purifiers at much greater than normal loading, with a washer for final purification.

Liquid reagents were also advocated by J. E. DAVIS, J. E. MILLS and C. RYDER, at the same meeting, for hydrogen sulphide removal from fuel gases produced under pressure. The iron oxide method cannot operate under high pressures to deal with high concentrations of this impurity. The high-pressure process as at present envisaged consists in washing the fuel gas, which may contain a high percentage (up to at least 30%) of carbon dioxide, with a solution of methylene blue in aniline. The hydrogen sulphide is oxidised to water and elemental sulphur. As the reaction is not reversible, complete removal can be obtained. The sulphur passes into solution and can be recovered in crystalline form by cooling the solution to a temperature lower than that in the absorption tower. The cooled solution is warmed, and re-oxidised by free oxygen ready for re-use. The process has operated satisfactorily on the scale of 200 cu. ft/hr, and a semi-scale plant is being constructed to operate at 50 times this throughput.

Computer Applied

DURING the course of a visit to the National Physical Laboratory to inspect the new Ace machine we learnt of some work which had been done on an earlier computer Deuce in examining the radial temperature distribution in a solid at equal time intervals when the solid was heated by a wire and chemical reaction could take place throughout the solid. The aim of the programme was principally to measure the activation energy of the chemical reaction. Commissioned by MR. R. A. W. HILL of I.C.I. Nobel Division the programme was carried out by MR. ALBASINY at the NPL. It involved solution of a pair of non-linear parabolic type partial differential equations by solving a set of non-linear implicit algebraic equations obtained by finite difference methods. This work will be published after more experimental work has been carried out.

In another programme of chemical engineering interest the machine has also been involved in work on frequency response analysis of oscillation about a computed steady state in a theoretical problem applied to an actual plant. The steady state condition was also computed on the machine.

Deuce is the engineered version, constructed by English Electric, of the pilot model of Ace which was handed over to the Science Museum after it had provided the team of mathematicians, logical designers, electronic engineers and mechanical engineers with the essential experience and "know-how" to undertake the more ambitious full-scale Ace project. The new machine which has now come into operation—said to be one of the world's largest and fastest—is six times the size of the original. The numbers and instructions have 48 binary digits equivalent to 14 decimal digits. The working store consists of 800 "words" and the backing store of four magnetic drums will contain a total of 32,768 "words." Mercury delay lines form the working stores and magnetic drums the backing stores for numerical data and instruction sequences; both punched card and magnetic tape equipment are provided for input and output. DR. A. M. UTTLEY, in charge of this work at the Laboratory announced that they would not build any more of these large machines. Any further models would be built by industry. NPL was now going over to research both on the machine and its uses.

Has Peat a Future?

ROUGHLY nine years of work on Scottish peat along several lines may shortly reach the stage of a market test for a briquetted product. A number of official agencies have been involved in the development, notably the Ministry of Power and the Department of Agriculture for Scotland. The main problem in using peat is, of course, its high water content. Straight from the bog it may contain 9 lb. of moisture per lb. of solids. By applying the so-called "milling" process this may be brought down to 50% moisture in three dry days, and the material may then be thermally dried down to 12% moisture, when its calorific value will be about 8000 Btu/lb. An important advance was made by applying the Madruck process, making the drying independent of climatic vagaries. The peat is cut to about ¾ in. size, dusted with dry peat powder and squeezed. Without this pre-dusting only "free" water is removed by pressure but the dry powder appears to act as a set of filter channels, permitting a breakdown of the colloidal character of raw peat and a greater degree of de-watering. Unlike coal, this fuel briquettes readily, perhaps due to flow of the waxes, and samples have been produced using a ram press. Market trials are now being arranged for products with 25% moisture, having a C.V. of about 5500-6000 Btu/lb. and for the material with 12% moisture. In addition work is in progress on peat as a source of chemicals, notably by solvent extraction of wax.

Technically, we understand that these lines of work are proving successful but it is the final economic appraisal which will decide whether Scottish peat has a future based on modern processing.

. . . by any other name

THE title says "Chemical Communications" but the journal,* publishing papers translated from *Chemické Listy*, includes a large proportion devoted to chemical engineering. In Vol. 23, No. 9, J. PROCHÁZKA, *et al.* describe a universal hydraulic analogue of heat exchangers. The device can be used for design of concurrent exchangers, countercurrent exchangers, split-flow exchangers, countercurrent condensers of superheated vapour and exchangers with three streams. Each stream is represented by a tube and for every case in which heat transfer occurs between two streams a capillary must be connected between the appropriate tubes. In the space here available the instrument cannot conveniently be described. Interested readers will find in the original account a description, references to earlier work and examples of cases of heat transfer where solution by means of the analogue is convenient and of others which cannot otherwise be solved. For certain types of exchangers, the authors suggest that the use of the analogues is convenient even if it is possible to assume that the values of the heat-transfer coefficients and of the water equivalents of the streams are constant, because the numerical computation is tedious. This applies where there are three streams of different fluids or in the general case of a split-flow exchanger, and others. Use of the analogue is also convenient where the values of the heat-transfer coefficients or water equivalents change significantly, and where it is necessary to consider heat losses (or gains) to the surroundings. In these cases the analogue can be used advantageously even for solving a system of heat exchangers.

* *Collection of Czechoslovak Chemical Communications.* Published monthly by the Czechoslovak Academy of Science.

That Embargo List

IN our December issue (p.650), we quoted a comment by MR. R. BARRINGTON BROCK, President of the Scientific Instrument Manufacturers Association, that the new embargo list on trade with Russia had been drawn up without consulting S.I.M.A. We invited the Board of Trade to comment on this and quote below from their letter of November 14.

"It is incorrect, therefore, to say that the 'revision . . . had been drawn up by the Board of Trade . . . [without consulting S.I.M.A.] . . .' There was no formal consultation with any body representative of individual industries as to the United Kingdom proposals for the revision of the embargo list; indeed, having in mind the strategic considerations on which the list was drawn up and the nature of the arrangements with the other co-operating countries, consultation of this kind could not properly have taken place. Nevertheless, we were fully aware of the views of the scientific instrument industry in the United Kingdom, which had been made known to us on many occasions through our normal contacts with the industry, and due weight was given to these views in formulating the United Kingdom proposals. We realise that the new list may not give the industry all that it had hoped for; but objective appraisal will show that it has released a substantial number of instruments from the strategic controls and has greatly widened the scope for legitimate trade."

MR. BARRINGTON BROCK states:

". . . I think it [the note] is a very accurate piece of reporting . . . I am afraid I disagree strongly with the remark that they are fully aware of the views of the scientific instrument industry. We have had a further meeting with the department concerned with embargoes and other meetings are projected. These meetings have clearly shown that until now it has been considered quite unnecessary to consult industry, whereas we as an industry feel that consultation is imperative, because of the impossibility of any academic scientist appreciating all the points which his banning of a particular product may raise. S.I.M.A. are proposing to approach the Board of Trade again with further lists of items which, in their opinion, are unreasonably banned, and it is hoped that some form of collaboration may be obtained later, although there is obvious resistance to this."

In concluding his letter, MR. BROCK thanked this journal for giving publicity to a matter of concern to the country as a whole.

Dignified Cold Facts

"KELVIN SCALE" is an interesting little publication of which we have just seen the first issue. It was formerly called "Cold Facts"—a title evidently now thought somewhat *infra dig.*—and contains useful information on cryogenics. Alongside a research note on designing the ADL Magnetic Refrigerator is an eminently practical one on gasketing for liquid oxygen. The U.S. Arthur D. Little Laboratories have carried out performance tests on Teflon, Kel-F, aluminium, lead and a combination of asbestos and Teflon. They were used between a pair of 6 in. 150 lb. A.S.A. raised-face stainless-steel welding neck flanges.

The test pieces were in turn bolted between the flanges, the assembly positioned vertically inside an evacuated chamber, then filled with liquid nitrogen and pressurized to 10 psig. Leakage through the flange assembly was

determined by the decay rate of a 29-in. vacuum in the chamber. The vacuum had to remain unchanged for at least an hour for a gasket to be classified as giving no leak.

Gasket	Finish of Mating Surfaces		
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Teflon	NT*	No Leak	Slight Leak
Kel-F	Leaked	NT*	Leaked
Aluminium	NT*	No Leak	NT*
Lead	No Leak	No Leak	No leak
Asbestos-Teflon	NT*	No Leak	No leak

* Not Tested.

Flanges with "phonographic" serrations are the most difficult to make tight, but $\frac{1}{16}$ in. lead or asbestos-Teflon proved to be satisfactory. There was no evidence that any of these materials would creep and result in leakage.

Cross-Flow of Steam and Steam-Gas Mixtures Past a Condenser Tube

WORK on the effect of cross-flow velocities on overall coefficients for steam condensing on a tube showed improvement up to velocities of 50 ft/sec., for filmwise condensation. With dropwise condensation significant improvements were shown up to velocities rather higher than this. These results, presented by T. FURMAN and H. HAMPSON before the Institution of Mechanical Engineers, formed part of a programme of comparison of filmwise and dropwise condensation of steam with some non-condensable gas present. A "steam tunnel" was developed in order to produce steam velocity up to 150 ft/sec., with a limited steam supply at atmospheric pressure. Nitrogen concentrations up to 6% were used. The investigation was limited to steam and steam-gas mixtures at near atmospheric pressure, condensing on a vertical tube. Experiments were made with both filmwise and dropwise condensation. The range of heat loads with "pure" steam for the filmwise tests was 20,000 to 290,000 Btu/ft²h. and for the dropwise tests 115,000 to 320,000 Btu/ft²h. The feed water was de-aerated and an air-free steam supply ensured. Owing to the incomplete present information on the water-side coefficients, it did not prove possible to present the steam-side coefficients, since these were considerably higher than the water-side coefficients, and a higher degree of accuracy is required in the estimation of the water-side coefficients than was possible from the available correlations. The different conditions around the tube precluded any surface temperature measurement from which a steam-side coefficient could be determined directly.

Ramifications of Food Research

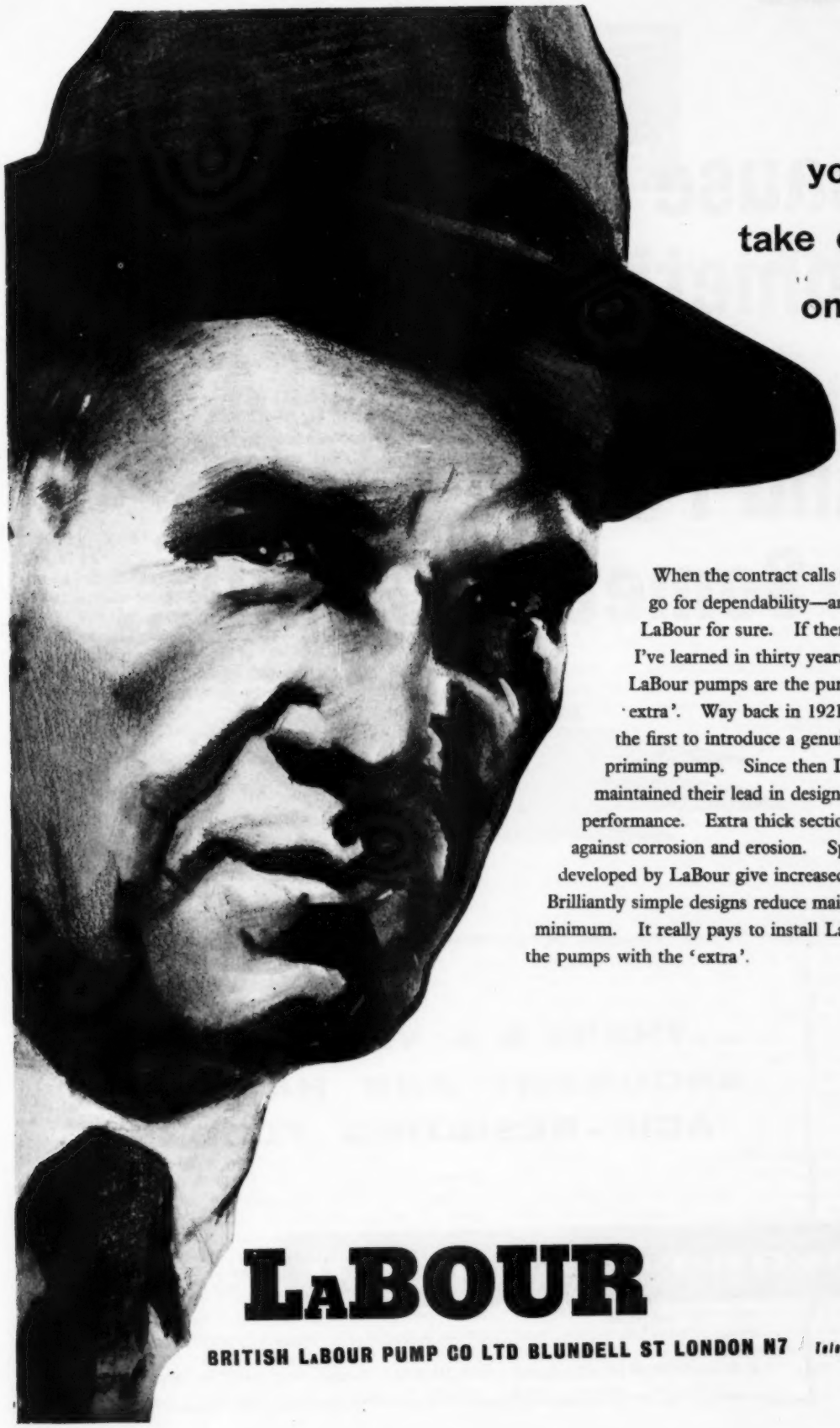
TOUCHING as they do on many branches of science, the research stations dealing with food include among their projects freezer design and the assessment of performance. In *Food Investigation*, 1957 (H.M.S.O. 5s.) there is a progress report on development of a vertical plate freezer for use at sea. Importance of this work lies in the fact that quick-freezing the early part of the white fish catch in distant waters would result in improvements in the average freshness of the catch and would improve the economics of distant-water fishing in several ways. Apparently, it has now become clear that the efficiency of heat transfer from the refrigerant to the freezing surface of the metal plate can have a considerable effect on the freezing time of even thick slabs of fish; the design of the plates, the flow rate and the state of the refrigerant are all important. It has therefore been decided to study separately the heat transfer from refrigerant to freezing surface and the heat flow from the fish to the freezing surface. A rig for steady-state tests of plates has been designed and the refrigerating system modified to allow of a wide range of flow rates of both primary and secondary refrigerants.

In addition, five major projects based on a semi-technical electrodialysis unit have been investigated in some detail. This has even included tentative costing. The projects are recovery of sucrose from beet molasses, improvement in the yield of sugar from beet by electrodialysis of thin juice, electrodialysis of milk whey, desalting of crude glycerine and desalting of glucose liquors prepared from hydrolysis of starch. Responsibility for the development and testing of improved membranes has now been transferred to the National Chemical Laboratory, Teddington, and arrangements for general development work on all aspects of the ion-exchange membrane project have been made by the National Research Development Corporation.

Process Monitoring by Radiometry

THE most popular form of in-line radiometric instruments both for the industrial use of radioisotopes and for use in the operational plants of U.K.A.E.A. are gamma radiation monitors. This is largely due to the high penetrative power of γ-radiation. Units can be used to monitor the gamma contents of vessels without the need for sampling; by virtue of this they can be readily adapted to existing plant installations with a minimum of plant modification. This feature could be a significant advantage where the process stream is under pressure, or highly toxic, and where internal access to the process stream is limited by physical considerations as in the case of small-bore pipes and vessels of complex internal construction. Further, the detector is an entirely sealed component, such as an ion-chamber, Geiger-Müller or scintillation counter of robust construction, and is thereby highly suited to plant conditions. The supply of detectors is no longer a problem and they can be readily replaced. There are, however, some difficulties which must be countered by good engineering design.

In addition, gamma-absorption techniques may be used to monitor such properties as density of a slurry or concentration of a solution. Density of a milled uranium ore and liquid mixture flowing in a 6 in. diameter steel pipe with $\frac{1}{4}$ in. wall has been monitored with an accuracy of ± 0.004 over the density range 1.4 to 1.6. As a gamma-radiation source the Cs-134 isotope with a radiation energy of 0.6 MeV was found by experiment to give the best results. The detection system employed was a 300-cm³ ionisation chamber, krypton-filled to enhance its sensitivity at the lower gamma energies and shielded with a $\frac{1}{4}$ in. lead jacket to minimise the response to scattered radiation. With the addition of briefer reference to alpha and beta monitoring the technique was discussed by H. BISBY and F. D. SEYMOUR in the course of a symposium on analytical instrumentation developed at Harwell. Organisers were the Society of Instrument Technology and the paper is being published in the "Transactions."



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A Code for Aluminium Pressure Vessels

SINCE the time of its first successful production by Oersted in 1825, advances in technique have brought aluminium, potentially the world's most abundant metal, to its present position of a popular material for kitchenware on the one hand, and, on the other, as an important industrial material of construction. If in its history there has been a turning point, then this must surely have been the advent of the HALL/HEROULT electrolytic reduction process. This process heralded an era of abundance of aluminium at a minute fraction of the cost offered by its predecessor, the sodium-based process of ST. CLAIR DEVILLE. Today the electrolytic reduction process, improved further by SØDERBERG'S invention, yields the metal in millions of tons at a price of 1.7s. per lb.; a price which has remained stable over a considerable period of time.

Following the advances in technology, there have been parallel developments of its physical metallurgy, so much so that today an immense range of alloys is available to the engineer, some offering tensile strengths approaching 40 tons/sq. in. If many of them are unsuitable for the hardships of life in a chemical plant, the engineer surely welcomes the addition to his repertoire of constructional materials the aluminium magnesium alloys.

Of late, aluminium has been much in the public eye. For one thing, the fate of the major portion of Britain's aluminium industry hangs in the balance, and whether "British Aluminium" becomes a fragment of the vast Mellon Alcoa interests or is absorbed in the less powerful Reynolds Tube Investments Group remains to be seen. Whatever the outcome, it is urgently to be desired that Britain's aluminium industry does not suffer the fate of the now stagnant magnesium industry.

Apart from such matters of national economy, there have been other events which have focused attention on the engineering aspects of aluminium, in particular the two recent symposia; first, the Low-Temperature Heat Transfer Conference organised recently by the Physical Society (whose Low Temperature Group has a very great influence on low-temperature technology generally), an event which revealed a number of innovations in the use of aluminium in this field. The other was the Aluminium Pressure Vessels Symposium sponsored by the Institution of Mechanical Engineers, an occasion at which the question of a code of design practice came under critical review.

From the earliest days of rational engineering design a quest was made to determine the relevant strength of materials by some simple test. Such is the tensile test from which is derived the ultimate tensile strength. For some time this has been a universal criterion for the allowable design stress for pressure vessels, and in recent years the correctness of this practice has been questioned—partly because phenomena other than tensile rupture may cause vessels to fail in practice. As was pointed out at the conference, the ultimate tensile strength is of no significance at all for the design of aluminium pressure vessels, and the economy of a procedure which makes use of very high safety factors—better termed factors of ignorance—is questionable.

The modern trend with pressure vessels is to design them closer and closer to the limits of the materials used, in which respect aluminium lags behind carbon steel. Moreover, most aluminium vessels are designed with the A.S.M.E. code in mind. This, coupled with the very wide experience which we now have of aluminium pressure vessels, makes the time ripe for considering the broadening of our existing codes of practice to include the design of aluminium-based pressure vessels, if not to set up a code exclusively for them.

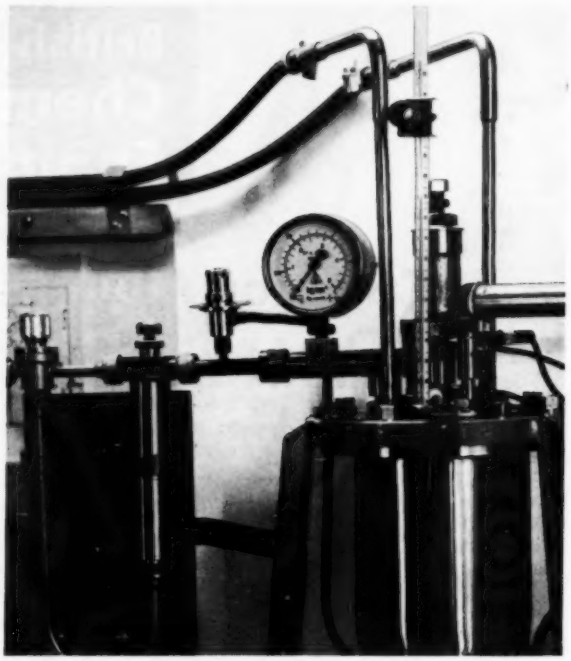
It is well to be clear about the functions of a code of practice. A designer is seldom in the happy position of having all the information necessary for a perfect design at his disposal. As a result assumptions are forced upon him, some of which may be matters of opinion rather than matters of fact. To some extent a code of practice will include the necessary assumptions, since it will have been drawn up by a number of individuals who, together, can assemble the widest experience of the subject available. The code is truly a money-saver, since it saves thousands of people the expense and trouble of making investigations for design data. Moreover, the individual approach will give a variety of conclusions, whereas the code of practice unifies experience and ensures uniformity in design.

Not to be overlooked is the advantage which a code offers of preventing the cautious engineer from overdesigning his structure, and, equally valuable, the risk of producing dangerous designs is minimised. If codes have a shortcoming, it is that they penalise the exceptional designer with the ability to design his vessels for the specific service conditions of their use.

The proposals put forward at the Symposium relating to future codes are therefore of considerable interest. In the paper which opened the conference R. T. ROSE and J. G. YOUNG proposed for the design pressure the internal pressure at which a pressure vessel becomes unsuitable for further use; this clearly recognises that a vessel may fail through a number of causes other than over-pressure. It aims to narrow the gap between design conditions and actual point of failure. One of the problems will be to assemble sufficient information on the possible sources of failure so that the engineer can design to whichever source is likely to be present with a particular vessel.

But what of the future? It is clear that immediately there is no prospect of a departure from the working stress method put forward in the A.S.M.E. code; and until sufficient data have been accumulated on creep, stress concentration, fatigue and other phenomena, it will not be possible to evolve a rational procedure. It is to be hoped that there will not be too long a delay in assembling this knowledge, but the impatient should realise that an enormous amount of work is required; for example, the investigations on fatigue require tests on small vessels extending over long periods.

66.045.2; 66.046.7; 541.123.2.



HEAT TRANSFER TO BOILING BINARY LIQUID MIXTURES PART I

by S. J. D. VAN STRALEN

A maximum value of the maximum nucleate boiling heat flux occurs in binary systems at a certain low concentration of the most volatile component. This effect is explained qualitatively to be connected with the simultaneous occurrence of a minimum average size of vapour bubbles, released from the heating surface. The influence of pressure on the absolute values of these maxima and on their ratios to the corresponding value in the less volatile pure component has been determined systematically in the range from 0.1-50 atma. The absolute values of the maxima increase gradually with increasing pressure in this range. Maximum ratios between 2.3 and 3.1 occur for the systems investigated, i.e., water-ethanol, water-1-propanol, water-1-butanol, water-1-pentanol, water-acetone, water-methylethylketone and water-ammonia, at relatively low pressures between 1 and 10 atma. With increasing pressure, all ratios approximate a value of 2.0 in the range from 10-50 atma. As a consequence heat flux values in nucleate boiling can be obtained with binary mixtures boiling in this range, exceeding considerably the maximum values, which are attainable with water boiling at an arbitrary pressure on the same heating surface.

Procedure and Survey of Results at Atmospheric and Sub-atmospheric Pressures

1.1. Method and Apparatus.

The rate of heat flow q from a heated wire to a boiling liquid is a function of $\Theta = t - T$, the difference in temperature between the heating surface and the bulk liquid. The curves representing the heat flux $\frac{q(\Theta)}{A}$, where A denotes the area of the heating surface, consist of three parts: the region of natural convection, in which no vapour bubbles are observed, the region of nucleate boiling, in which vapour bubbles are generated on special spots of the surface, and the region of film-boiling, in which a gradually increasing area of the surface is covered with a coherent layer of vapour. In the regions of convection and nucleate boiling the values of Θ are small or moderate, in contradistinction to the region of film-boiling, where Θ amounts to higher values, up to the melting point of the wire.[8, 20] As a consequence the coefficient of heat transfer

$$h = \frac{q(\Theta)}{A\,\Theta}$$

amounts to appreciably high values in the regions of convection and nucleate boiling only.

In principle, the method described by McAdams, *et al.*[12] has been used to determine the heat-transfer curves up to the maximum of nucleate boiling for some mixtures of the binary systems water-methylethylketone and water-1-butanol, including the pure components. For that purpose a gradually increasing direct current was passed through a horizontal platinum wire, of diameter D, a central portion of which was isolated as a test section by the use of thin platinum potential taps. This section served as the heating surface and at the same time as a resistance thermometer. The heat flux $\frac{q}{A}$ and the temperature difference Θ were directly calculated from measurements of the potential drop E across the test section, having a length L, and of the current I,[12, 19] since the specific resistance of platinum is known as a function of temperature.[2] We have:

$$\frac{q}{A}\ (\text{cal. sec.}^{-1}\ \text{cm.}^{-2}) = 0.07604\,\frac{EI}{LD}\ (\text{volts amperes cm}^{-2}) \qquad \ldots.(1)$$

and:

$$\Theta = \psi(T) \cdot \left(\frac{E}{IR_T} - 1\right) - \frac{D}{8k} \cdot \frac{q}{A} \qquad \ldots.(2)$$

S. J. D. van Stralen, *since 1953, has been engaged in research on heat transfer to boiling binary liquid mixtures at the Laboratory of Physics and Meteorology, Agricultural University, Wageningen, The Netherlands, under the direction of Prof. Dr. W. R. van Wijk, and at first in co-operation with Ir. A. S. Vos.*

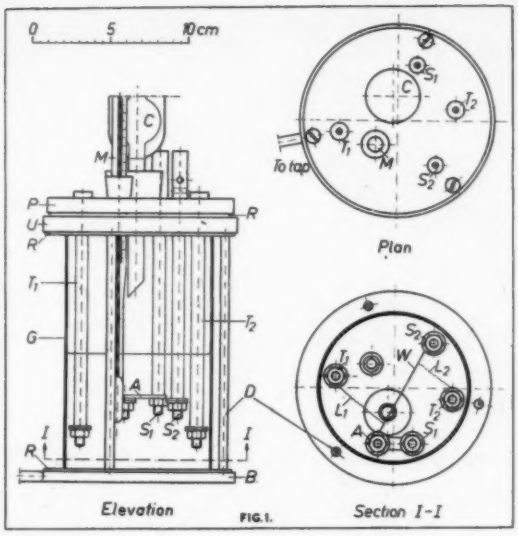


FIG. 1.

Here R_T denotes the resistance of the test section at the boiling temperature T of the liquid in ohms, which was measured by passing a small current through the circuit while the wire was immersed in the boiling liquid. The multiplication factor $\psi(T)$ can be calculated from:

$$\psi(T) = \frac{1 + BT - CT^2}{B - 2CT} \qquad \ldots (3)$$

In the term $-\frac{D}{8K}\cdot\frac{q}{A}$ in Equation (2) the radial gradient in temperature within the wire is taken into account. This term, in which k denotes the thermal conductivity of platinum (0.17 cal. sec.$^{-1}$ cm.$^{-1}$ °C^{-1}), represents only a small value as wires with diameters of 0.02 cm. were used. For these, physically pure (99.99%) wires B was taken as 3.9788×10^{-3} and C was taken as 5.88×10^{-7} if T is expressed in degrees centigrade. The test sections had an average length of approximately 5 cm., and the potential taps had relatively small diameters of 0.005 cm. The wires

Fig. 1. Diagram of glass boiling vessel. A = *revolving arm;* B = *nickel-coated brass base;* C = *total reflux condenser;* D = *draw bars;* G = *glass cylinder;* M = *calibrated thermometer;* N = *neoprene packing;* L_1 *and* L_2 = *potential leads;* P = *Pertinax cover;* S_1, S_2, T_1 *and* T_2 = *nickel-coated brass-bars;* W = *heating wire.*

Symbols Used

A = area of surface of test wire, sq. cm.;
B, C = constants in platinum temperature equation, °C^{-1}, °C^{-2};
D = diameter of test wire, cm.;
E = potential drop across test wire, V;
F = constant in vapour-bubble growth equation, cm. sec.$^{-\frac{1}{2}}$ °C^{-1};
G = vaporised molar fraction at heating surface;
$h = \frac{q}{A\Theta}$ = coefficient of heat transfer in test surface, cal. sec.$^{-1}$ cm.$^{-2}$ °C^{-1};
$h_{max.} = \frac{q_{max.}}{A} \Big/ \Theta_{max.}$ = maximum coefficient of nucleate boiling-heat transfer in test surface, cal. sec.$^{-1}$ cm.$^{-2}$ °C^{-1};
I = electrical current strength through test wire, A;
k = thermal conductivity of platinum, cal. sec.$^{-1}$ cm.$^{-1}$ °C^{-1};
K = equilibrium constant of most volatile component in binary liquid mixture;
L = length of test section of heating wire, cm.;
n = number of degrees of mercury-in-glass thermometer, emergent from the lead or silicon oil in the thermometer tube;
p = absolute pressure, kg.* cm.$^{-2}$;
p_c = critical pressure of water, kg.* cm.$^{-2}$;
$p_r = \frac{p}{p_c}$ = reduced pressure of water;
q = heat flow in test surface, cal. sec.$^{-1}$;
$\frac{q}{A}$ = heat flux in test surface, cal, sec.$^{-1}$ cm.$^{-2}$;
$\left(\frac{q}{A}\right)_{max.}$ = maximum nucleate boiling-heat flux in test surface, cal. sec.$^{-1}$ cm.$^{-2}$;
r = radius of growing vapour bubble, cm.;
R_T = electrical resistance of test wire at boiling temperature of liquid, Ω;
t = growing time of vapour bubble before leaving the neighbourhood of the heating surface, sec.;
$t_{max.} = \Theta_{max.} + T$ = maximum temperature of heating surface occurring at maximum nucleate boiling, °C;
T = boiling temperature of liquid, °C;
$T_c = T_o + \triangle T_1 + \triangle T_2$ = corrected observed boiling temperature of liquid, °C;
T_o = observed boiling temperature of liquid, °C;
T_p = boiling temperature of water at pressure p according to vapour pressure table, °C;
T_A, T_B, T_{Az} = boiling temperature of component A, B and azeotrope at atmospheric pressure, °C;
x = molar fraction of most volatile component in liquid boundary layer surrounding a vapour bubble in a binary liquid mixture;
x_o = molar fraction of most volatile component in bulk liquid;
$x_{o,m}$ = molar fraction of most volatile component in bulk liquid, at minimum average bubble size;
$\triangle T$ = temperature difference between dew temperature of vapour bubble and boiling temperature of bulk liquid, °C;
$\triangle T_1$ = calibration error of mercury thermometer, °C;
$\triangle T_2$ = stem correction of mercury thermometer, °C;
$\triangle \tau$ = superheating of boiling water; °C;
$\psi(T)$ = multiplication factor in temperature difference equation, °C;
Θ = temperature difference between heating surface and boiling liquid, °C; and
$\Theta_{max.}$ = temperature difference between heating surface and boiling liquid at the maximum of nucleate boiling, °C.

Fig. 2. Heat flux for convection and nucleate boiling to water as a function of temperature difference between heating surface and liquid at atmospheric pressure and at pressures of 42, 20 and 10 cm Hg. The figures at the curves denote the number of nuclei-generating vapour bubbles on a platinum heating wire with a length of approximately 5 cm and a diameter of 0.02 cm. Wire 1: 76 cm Hg (▽), 10 cm Hg (●); wire 2: 42 cm Hg (○), 20 cm Hg (■); wire 3: 76 cm Hg (▼).

Fig. 3. Water-methylethylketone. Heat flux for convection and nucleate boiling to water and to 4.1% (○), 20% (■), 52% (△), 88.5% (●) and 100% (□) wt. of M.E.K. as a function of temperature digerence between heating surface and liquid at atmospheric pressure. The figures at the curves for 0%, 4.1% and 100% wt. of M.E.K. denote the number of nuclei-generating vapour bubbles on the platinum heating wires with a length of approximately 5 cm and a diameter of 0.02 cm.

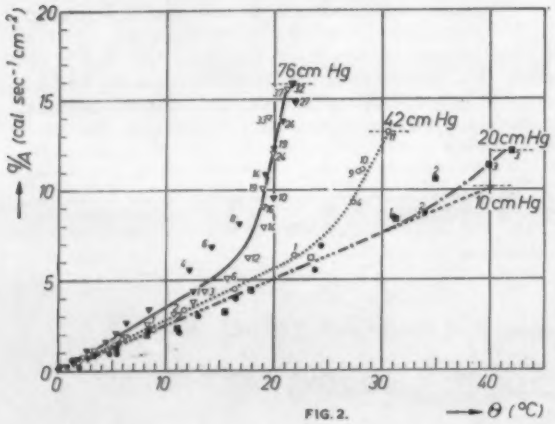


FIG. 2.

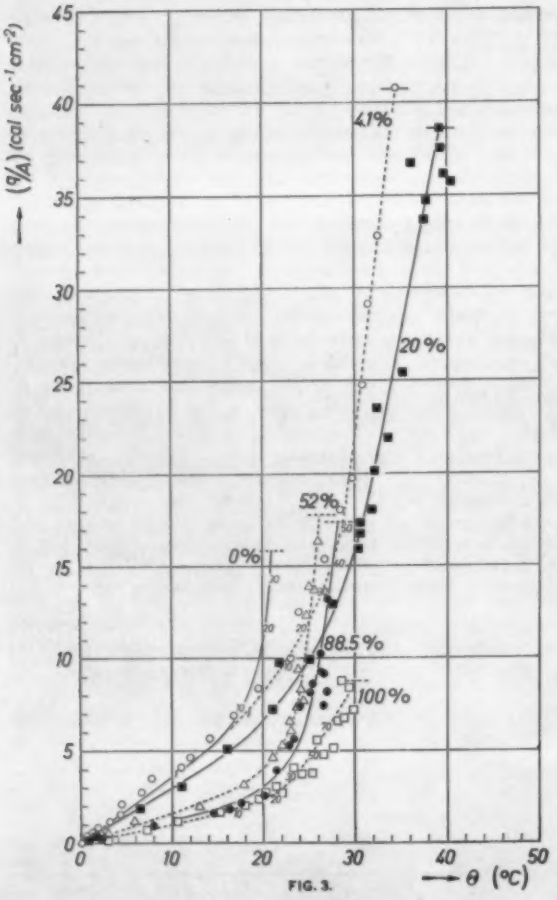
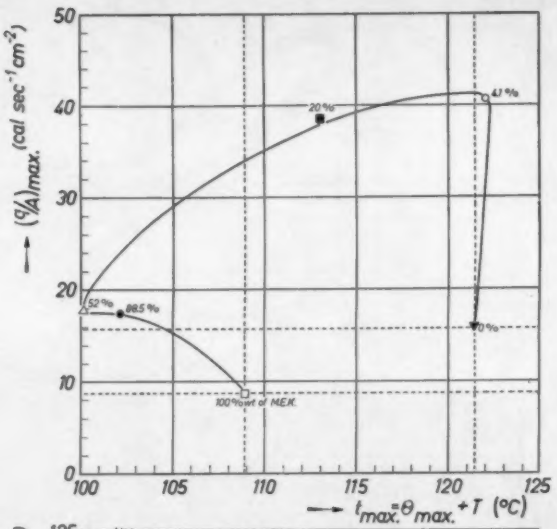


FIG. 3.



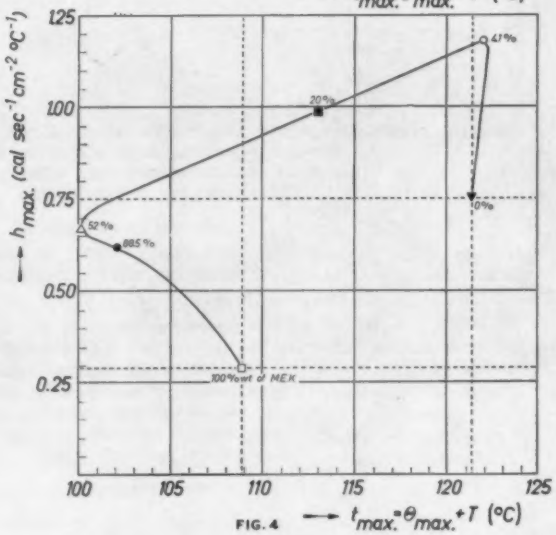


FIG. 4

Fig. 4. Water-methylethylketone. Maximum heat flux and maximum coefficient of heat transfer for nucleate boiling as a function of temperature of the heating surface at atmospheric pressure. The dotted lines serve for a comparison of the mixtures with the pure components; % denotes % wt. of M.E.K.

Fig. 5. Water-methylethylketone. Heat flux for convection and nucleate boiling to water and to 4.1% and 100% wt. of M.E.K. as a function of temperature difference between heating surface and liquid at atmospheric pressure and at a pressure of 42 cm Hg. The figures at the curves denote the number of nuclei-generating vapour bubbles on the platinum heating wires with a length of approximately 5 cm and a diameter of 0.02 cm Water (. . . . .) wires 1 and 3: 76 cm Hg; wire 2: 42 cm Hg. 4.1% wt. of M.E.K. (——) wire 4: 76 cm Hg (▽); wire 5: 42 cm Hg (▼). M.E.K. (– – ——) wire 4: 76 cm Hg (○); wire 6: 42 cm Hg (●).

Fig. 6. Water-1-butanol. Heat flux for convection and nucleate boiling to water (○●) and to 1.3% (■) and 100% wt. of 1-butanol (▲) as a function of temperature difference between heating surface and liquid at atmospheric pressure. The figures at the curves denote the number of nuclei-generating vapour bubbles on the platinum heating wires with a length of approximately 5 cm and a diameter of 0.02 cm.

Fig. 7. Water-methylethylketone. Maximum heat flux as a function of composition at atmospheric pressure. Measurements carried out with the same wire are represented by the same figures. Az = azeotrope. The dotted vertical lines indicate the boundaries of the region of demixing at azeotropic boiling point. The other curves represent ΔT as a function of composition for a constant vaporised molar fraction G. ΔT is the difference between dew temperature of the vapour bubbles and boiling temperature of the original liquid. The numbers near these curves are the values of G.

Fig. 8. Water-1-butanol. Maximum heat flux as a function of composition at atmospheric pressure. Measurements carried out with the same wire are represented by the same figures. Az = azeotrope. The dotted vertical lines indicate the boundaries of the region of demixing at azeotropic boiling point. The other curves represent ΔT as a function of composition for a constant vaporized molar fraction G. ΔT is the difference between dew temperature of the vapour bubbles and boiling temperature of the original liquid. The number near these curves are the values of G.

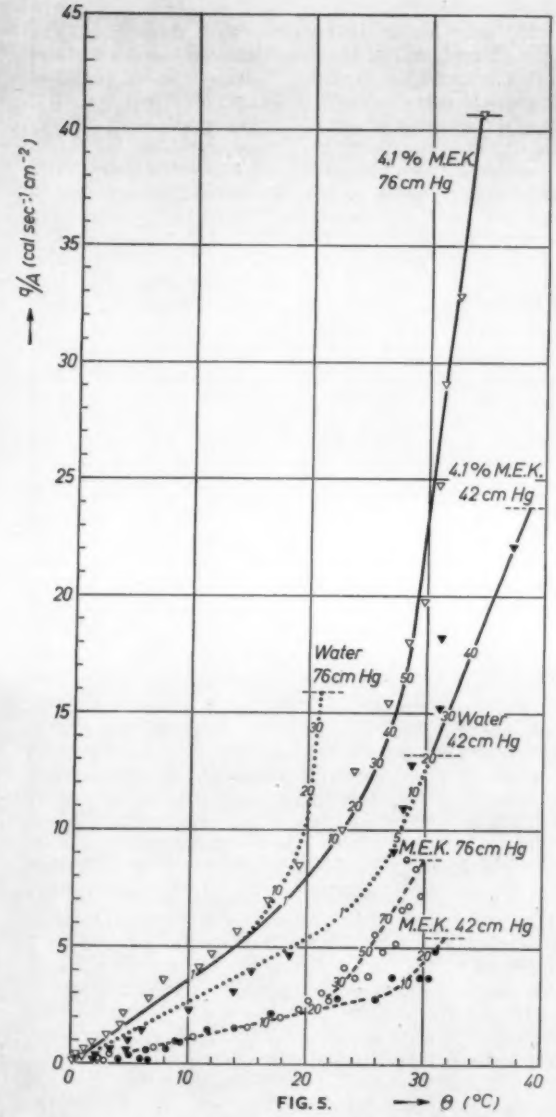


FIG. 5.

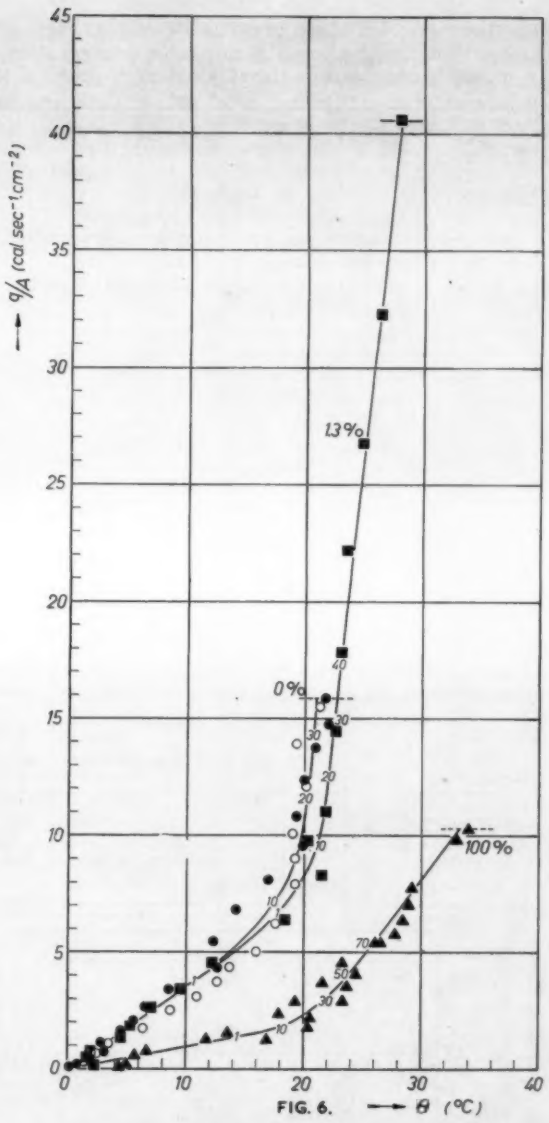


FIG. 6.

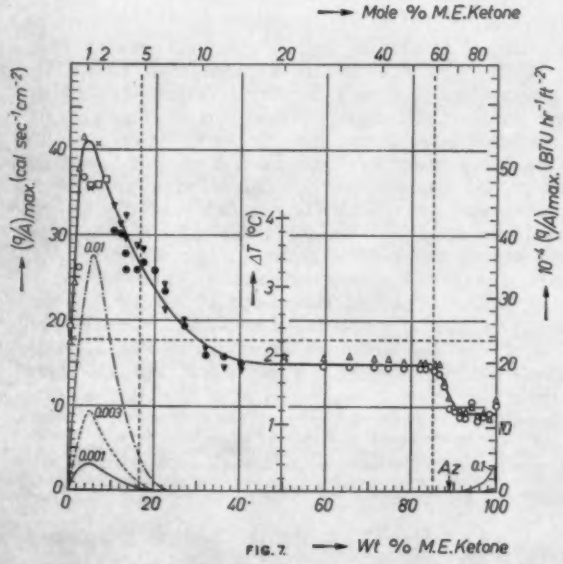


FIG. 7. Wt % M.E.Ketone

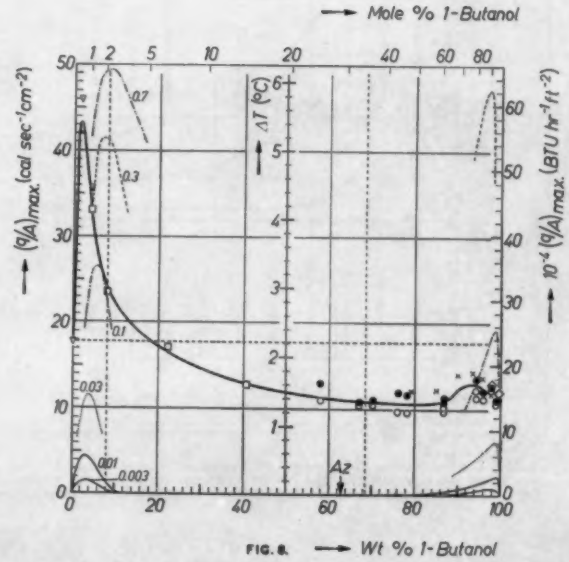


FIG. 8. Wt % 1-Butanol

had been annealed at red heat (1000°C) for 15 min.

According to Equations (1) and (2) the determination of a heat-flux curve was restricted to measurements of the potential drop across the test section of the wire, of the heating current, and of the dimensions of the test surface. For this purpose the wire had been connected in series with a standard-resistance of manganin. The potential drop across this resistance of high accuracy was directly proportional to the heating current. This tension and that across the test section were recorded on a potentiometer, after reduction to suitable values, by application of tapped shunts. Influence of temperature on the dimensions of a heating wire measured at room temperature is negligible.

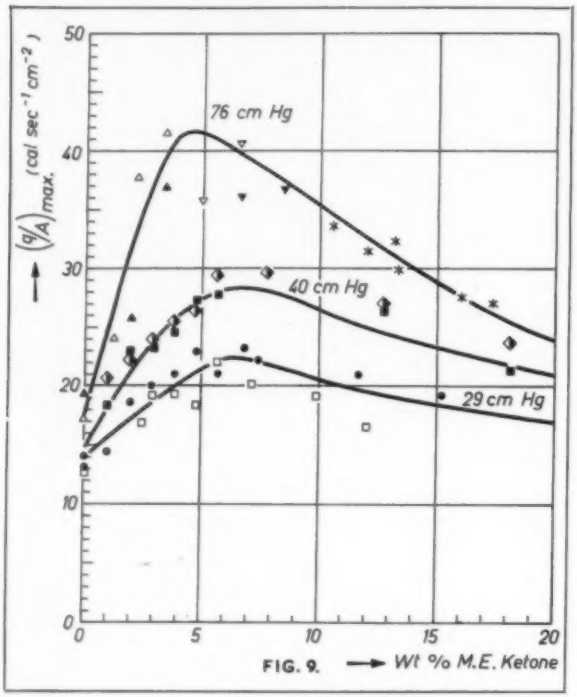


FIG. 9.

Fig. 9. Water-methylethylketone. Maximum heat flux as a function of composition at 76 cm Hg (△▲▽▼★), 40 cm Hg (■◆) and 29 cm Hg (●□). Measurements using the same wire are represented by the same figures.

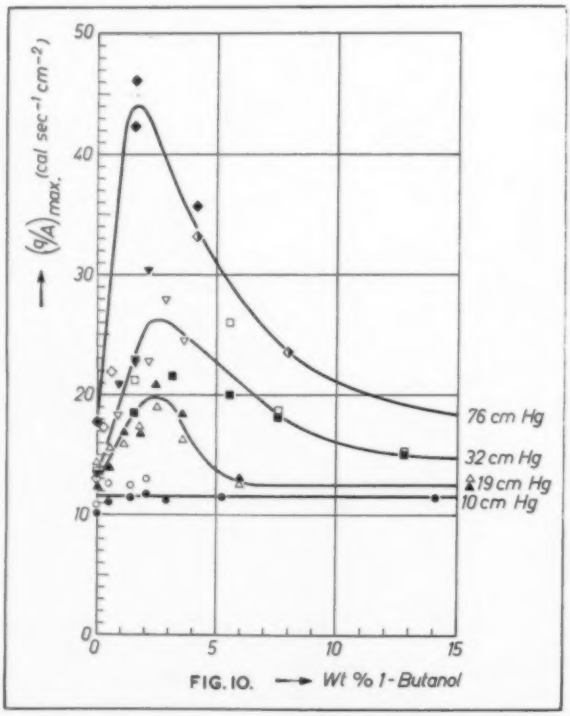


FIG. 10.

Fig. 10. Water-1-butanol. Maximum heat flux as a function of composition at 76 cm Hg (◆◆), 32 cm Hg (■□▽▼◇), 19 cm Hg (△▲) and 10 cm Hg (○●). Measurements with the same wire are represented by the same figures.

The boiling vessel (Fig. 1) consisted of a glass cylinder with ground end-faces. The nickel-coated-brass cover ring and bottom plate were fastened to the cylinder by means of draw bars, and neoprene rings, which were boiled in a caustic solution to dissolve free sulphur,[17] were used for packing. A Pertinax cover was provided with four nickel-coated-brass bars. The wire was stretched between two bars, while the potential leads were attached to the remaining bars, which were placed at a suitable distance from the wire. A total-reflux condenser was mounted on the cover plate, and the boiling vessel was partly filled with liquid; it was heated from below by a Bunsen flame to the boiling temperature desired. Uniform boiling was maintained during the experiments, as heat losses were compensated by the flame. The combined action of a water jet pump and a Cartesian manostat ensured a constant vacuum in experiments at sub-atmospheric pressures. In all cases the boiling temperature could be kept constant within 0.5°C.

1.2. Results.

1.2.1. Heat Flux for Convection and Nucleate Boiling as a Function of Temperature Difference Between Heating Surface and Liquid.

1.2.1.1. *Water.*

The heat flux $\frac{q}{A}$ to boiling water was determined as a function of the temperature difference Θ between heating surface and liquid. Results at atmospheric pressure and at pressures of 42, 20 and 10 cm. Hg are shown in Fig. 2. The figures by the curves denote the number of nuclei at which vapour bubbles were generated on a heating surface of 0.31 cm.^{2} The number of active nuclei in the nucleate boiling part of a curve increased gradually with increasing temperature difference, until film-boiling started.

The average diameter of the bubbles leaving the wire amounted to approximately 0.2 cm. at atmospheric pressure (compare Fig. 12-1). The reproducibility of the results at atmospheric pressure is satisfactory, as follows from the data obtained with two different heating wires.

Only two nuclei generating vapour bubbles, with relatively large diameters of approximately 1.1 cm. (compare Fig. 12-2), were observed at a pressure of 10 cm. Hg. Apparently the decreasing number of vapour bubbles at lower pressures was setting up smaller circulation currents in the liquid layer surrounding the wire.[11]* Consequently the maximum of nucleate boiling decreased with decreasing pressure and approximated a value of 8 cal. sec.$^{-1}$ cm.$^{-2}$ at pressures below 10 cm. Hg; in this case film-boiling started immediately at the appearance of only one relatively large-vapour bubble on the wire (see Fig. 15, to be published in the February, 1959, issue).

As a second consequence the slope of the curves in the region of nucleate boiling decreased at lower pressure; at 10 cm. Hg the region of nucleate boiling tallied fairly well with the linear continuation of the natural convection part of the curve.

* *Not only the number of active nuclei, but also the average frequency of bubble formation on a nucleus increases with increasing pressure, i.e., decreasing bubble size,[5] the more so as at a pressure of 10 cm. Hg only intermittently was a column of vapour bubbles generated on the heating wire (compare section 1.2.2.4.2 and Figs. 12-1 and 12-2).*

1.2.1.2. *Binary systems: water-methylethylketone and water-1-butanol.*

The heat flux for convection and nucleate boiling to some mixtures of the binary systems water-M.E.K. (methylethylketone) and water-1-butanol has been investigated in comparison to the behaviour of the pure components.

Fig. 3 shows the heat flux $\frac{q}{A}$ as a function of temperature difference Θ between heating surface and liquid to water, to 4.1% wt of M.E.K., to 20% wt of M.E.K., to 52% wt of M.E.K., to the azeotropic mixture containing 88.5% wt of M.E.K. (compare Table 1), and to M.E.K. respectively at atmospheric pressure. The curves are similar, but the maxima of nucleate boiling-heat flux differ considerably.

A maximum in maximum nucleate boiling-heat flux (compare Fig. 7) occurred in the mixture containing 4.1% wt of M.E.K., and this value amounts to 2.5 times the maximum in water. A gradual decrease of heat transfer occurred with increasing concentration of M.E.K. in mixtures which contain M.E.K. in excess.

The maximum nucleate boiling-heat flux $\left(\frac{q}{A}\right)_{max.}$ and the maximum coefficient of heat transfer $h_{max.} = \left(\frac{q}{A}\right)_{max.} / \Theta_{max.}$, at atmospheric pressure are represented in Fig. 4 as a function of the corresponding temperature of the heating surface $t_{max.} = \Theta_{max.} + T$, where T denotes the boiling temperature of the liquid. The maximum heat flux in 4.1% wt of M.E.K. occurs approximately at the same temperature of the wire as the maximum in water. In the mixtures containing 52% and 88.5% wt of M.E.K., the maximum heat flux is nearly equal to the value in water, but the corresponding temperature of the heating surface is approximately 20°C lower since the boiling temperature T is approximately 75°C. These mixtures consist of two liquid phases.

In Fig. 5 the heat flux to water, and to 4.1% and 100% wt of M.E.K. is shown as a function of temperature difference between heating surface and bulk liquid, at atmospheric pressure and at a pressure of 42 cm. Hg respectively. The maximum nucleate boiling-heat flux to 4.1% wt of M.E.K. exceeded considerably the corresponding value for water at both pressures investigated. This phenomenon could be explained by the fact that the average size of vapour bubbles, leaving the heating surface, was smaller in this mixture than in water at the same pressure (compare section 1.2.2.4 and Figs. 12-1 and 12-3).

The curves have shifted towards lower heat transfer at the same temperature difference, and lower maximum values in nucleate boiling occurred with decreasing pressure. At atmospheric pressure the behaviour of 1.3% wt of 1-butanol is quite similar to that of 4.1% wt of M.E.K. (Figs. 6 and 8).

1.2.2. Maximum Nucleate Boiling-heat Flux as a Function of Binary Mixture Composition.

1.2.2.1. *Results at Atmospheric Pressure.*

The influence of concentration upon the maximum nucleate boiling-heat flux was investigated systematically at atmospheric pressure for aqueous binary mixtures of M.E.K., acetone and the lower aliphatic alcohols. In addition, the maximum heat flux to mixtures consisting of two organic liquids, i.e., dioxane-methanol and 2-chloroethanol-di-iso-propylether, were investigated.[20] Distilled water was used. The M.E.K. and the 1-pentanol were chemically pure, the latter was the furfural free grade, the 1-butanol had a boiling range from 115-117°C and the other organic liquids were of commercial grade.

In these investigations the heating wires were heated with alternating current and the temperature difference between wire and bulk liquid was not measured. Only the voltage drop across the wire, the heating current and the dimensions of the wire were determined; the maximum heat flux was then calculated from Equation (1).

The maximum of nucleate boiling-heat flux could be determined easily as burnout of the wire or film-boiling occurred. In the latter case the resistance of the platinum wires increased suddenly and, consequently, the voltage drop across the wire increased and the heating current decreased at the same time.

Data concerning the boiling point and azeotrope of some of these binary systems investigated is given in Table 1. A more complete survey has been given elsewhere.[20]

In all systems investigated a maximum value in the maximum nucleate boiling-heat flux occurred at a certain low concentration of the most volatile component (Figs. 7 and 8). The higher the number of carbon atoms in the aliphatic alcohol and ketone series, the more this maxi-

Table 1. Survey of Data Concerning Boiling Point and Azeotrope of Binary Systems at Atmospheric Pressure

Component		*Boiling point*			*Azeotrope*	
A	*B*	T_A (°C)	T_B (°C)	T_{Az} (°C)	%*B* *Wt.*	%*B* *Mole*
water	ethanol	100	78·3	78·1	95·6	89·4
water	1-propanol	100	97·2	87·7	71·8	43·3
water	1-butanol	100	117·8	92·4	62·0	28·4
water	1-pentanol	100	137·8	95·8	46·1	14·9
water	acetone	100	56·4		non-azeotrope	
water	methylethylketone	100	79·6	73·5	88·7	66·6
water	ammonia	100	−34		non-azeotrope	

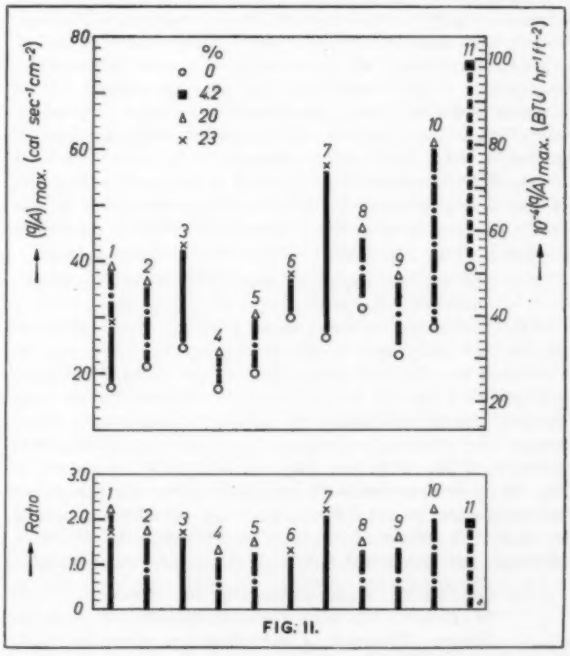


Fig. 11. Water-methylethylketone. Maximum nucleate boiling flux of different wires at atmospheric pressure to 4.2%, 20% and 23% wt. of M.E.K. in comparison with maximum nucleate boiling heat flux to water. 1. Pt (D = 0.02 cm); 2. Ag (0.02); 3. Cu (0.025); 4. Ni (0.02); 5. oxidised Ni (0.02); 6. Fe (0.025); 7. W (0.041); 8. constantan (0.02); 9. nichrome V (0.02); 10. oxidised nichrome V (0.02); 11. oxidized nichrome V (0.08).

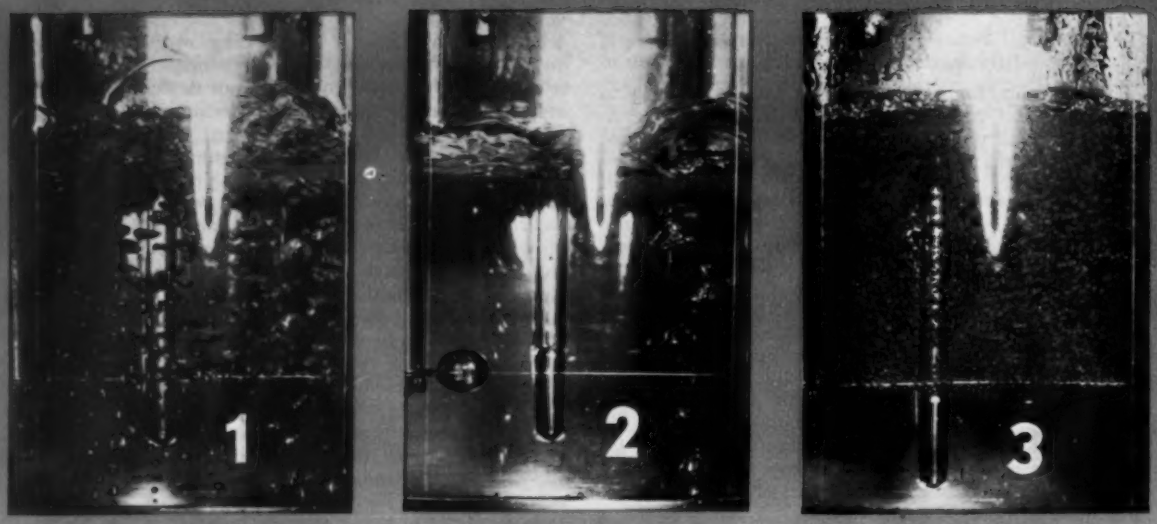


Fig. 12. Water-methylethylketone. Photographs showing the size of vapour bubbles and the number of nuclei on a platinum heating wire with a length of 6.4 cm and a diameter of 0.02 cm. 1. Water at atmospheric pressure (boiling temperature 100.50°C); heat flux 13.3 cal. sec.$^{-1}$ cm^{-2}; 2. Water at a pressure of 10 cm Hg (boiling temperature 50.95°C); heat flux 6.5 cal. sec.$^{-1}$ cm^{-2}; 3. 4.1% wt. of M.E.K. at atmospheric pressure (boiling temperature 87.95°C); heat flux 17.8 cal sec.$^{-1}$ cm^{-2}.

mum is shifted towards a lower concentration of the organic component. Partial miscibility showed no effect on the continuity of the maximum heat-transfer curves.

1.2.2.2. *Results at Subatmospheric Pressures.*

The influence of concentration on the maximum nucleate boiling-heat flux was also investigated systematically at several sub-atmospheric pressures for aqueous binary mixtures of M.E.K., acetone and the lower aliphatic alcohols. Restriction was made now to mixtures containing water in excess.[16] Again a maximum value in maximum nucleate boiling-heat flux occurred at a certain low concentration of organic component, which was approximately independent of pressure (Figs. 9 and 10). The absolute values of the maxima and even the ratio of these maxima to the maximum value in water at the same pressure diminished gradually with decreasing pressure.[16] At a pressure of 10 cm. Hg no maxima were present in the curves (Fig. 10), as the size of vapour bubbles had been increased to the extent that the heating wires passed immediately into film-boiling if only one bubble appeared (compare 1.2.1.1).

1.2.2.3. *Influence of Different Heating Wires on the Maximum Heat-flux Values in Nucleate Boiling.*

With the object of ascertaining if the occurrence of maxima in maximum nucleate boiling-heat flux can be attributed to physical properties of the liquid mixtures, and not to a special combination of heating surface and mixture, wires consisting of different metals have been used.[18] The observed maximum nucleate boiling-heat flux values in 4.2%, 20% and 23% wt of M.E.K. are given in Fig. 11 in comparison with the ratio to the corresponding values in water at atmospheric pressure. An increase similar to that with platinum wires was observed in all cases, although the numerical value of the ratio varied slightly.

1.2.2.4. *Qualitative Explanation of the Occurrence of Maxima in the Maximum of Nucleate Boiling for Binary Systems, Containing a most Volatile Component.*

1.2.2.4.1. *Growth of vapour bubbles in boiling binary mixtures.*

The following considerations on the growth of vapour bubbles originated from W. R. VAN WIJK[19, 20]; it is thus apparent that the average size of vapour bubbles in a boiling binary mixture, of which one component is the more volatile in a region including low concentrations, is smaller than in the pure less volatile component. Owing to a difference in composition between the liquid boundary layer immediately surrounding a vapour bubble *in these mixtures*, and the bulk liquid, the superheating of the bulk liquid $\triangle\tau$ with respect to the dew temperature of the vapour bubbles is decreased by an amount

$$\triangle T = T(\text{æ}) - T(\text{æ}_o), \qquad \ldots . (4)$$

where

$$\text{æ} = \frac{\text{æ}_o}{1 + \{K(\text{æ}) - 1\}\, G} \qquad \ldots . (5)$$

when equilibrium flash vaporisation is assumed. In these equations æ = concentration of most volatile component in the boundary layer, æ_o = concentration of this component in the bulk liquid, and $K(\text{æ})$ = equilibrium constant of this component. Further, $T(\text{æ})$ = boiling temperature of boundary layer = dew temperature of vapour bubbles, and $T(\text{æ}_o)$ = boiling temperature of bulk liquid. According to JAKOB and FRITZ,[7] $\triangle\tau$ amounts to some tenths of a degree centigrade for water boiling at atmospheric pressure; $\triangle\tau$ (the difference in boiling temperature of the bulk liquid and the dew temperature of the vapour bubbles *in a pure component*) causes the bubbles to grow during passage through the superheated liquid, and is assumed to have the same value for all mixtures containing water in excess.

$\triangle T$ depends on the molar fraction G, which is vaporised immediately at the heating surface. This fraction is small, and consequently the transfer of latent heat from the surface is only a small fraction of the total heat transfer.[11] The curves representing $\triangle\ T(\text{æ}_o)$ for a constant value of G show a maximum at a certain low concentration of the most volatile component $x_{o,\,m}$ (Figs. 7 and 8), as

$$\triangle T(O) = \triangle T(\text{azeotrope}) = O$$

In this way the curves representing the resulting effective superheating

$$\triangle\tau - \triangle T(\text{æ}_o) \qquad \ldots . (6)$$

4.41% wt. of M.E.K. at a pressure of 21 cm Hg (boiling temperature 54.62°C); heat flux 8.9 cal. sec.$^{-1}$ cm^{-2}; 5. 12.7% wt. of M.E.K. at atmospheric pressure (boiling temperature 76.70°C); heat flux 16.9 cal. sec.$^{-1}$ cm^{-2}; and 6. 12.7% wt. of M.E.K. at atmospheric pressure (boiling temperature 76.73°C); heat flux 6.4 cal. sec.$^{-1}$ cm^{-2}.

in a binary system, show a minimum at the same concentration $\alpha_{o,m}$, which depends on the equilibrium data of the system and on the value of G. The selected value of G has been determined by introducing the condition:

$$\Delta\tau - \Delta T(\alpha_{o,m}) = O \qquad \ldots (7)$$

One finds $G = 0.01$ for the systems containing water and a lower aliphatic alcohol (Fig. 8) and $G = 0.002$ for water — M.E.K. (Fig. 7).

According to PLESSET AND ZWICK[15] and FORSTER AND ZUBER,[4] the asymptotic approximation for the radius r of a separate vapour bubble in a pure component can be expressed by:

$$r = F\sqrt{t}.\Delta\tau, \qquad \ldots . (8)$$

where F is a factor, depending on physical quantities of the liquid concerned. This approximation is valid when the time t of growth has exceeded a certain small limit. Here we assume F to be constant for mixtures containing water in excess, and replace Equation (8) by:

$$r = F\sqrt{t}\left\{\Delta\tau - \Delta T(\alpha_o)\right\} \qquad \ldots . (9)$$

It is now apparent from Equations (7) and (9), that the average size of vapour bubbles, released from the heating surface in a binary system, shows a minimum value at a certain concentration $\alpha_{o,m}$ of the most volatile component.

1.2.2.4.2. *Relation between smaller size of vapour bubbles and higher maxima in nucleate boiling.*

A heating wire is surrounded by a small liquid boundary layer, through which heat is transferred by conduction only. The formation of each vapour bubble on the wire means a disturbance in the laminar boundary layer, and consequently higher heat transfer due to the circulation currents which are set up in this way. At the maximum of nucleate boiling, film-boiling (LEIDENFROST phenomenon) occurs, as vapour bubbles merge into each other in the neighbourhood of the heating surface. Obviously the maximum number of disturbances per unit area per sec—this is the total number of vapour bubbles per unit area per sec, and can be written as the number of active nuclei per unit area multiplied by the average frequency of bubble formation on a nucleus—which can be present at the maximum of nucleate boiling, should increase with decreasing size of the bubbles.*

Following this line of thought in binary systems containing a most volatile component, a maximum nucleate boiling-heat flux can be expected at the concentration $\alpha_{o,m}$ of minimum average size of vapour bubbles. All maxima predicted by the theory have actually been observed (Figs. 7 and 8), e.g., two maxima in water-1-butanol. The second, less pronounced, maximum occurs at a high concentration of organic component, where water is the most volatile component. The concentration of the main maxima $\alpha_{o,m}$ is shifted towards smaller values for a larger number of carbon atoms in the aliphatic alcohol and ketone series, in concurrence with the experimental results given in section 1.2.2.1. In the same way the maximum nucleate boiling-heat flux to water should increase with increasing pressure in the region investigated (Figs. 2, 14 and 15) as a consequence of the diminishing size of vapour bubbles (compare section 1.2.1.1).

The concentration $\alpha_{o,m}$ of the maxima occurring at several sub-atmospheric pressures in binary mixtures, containing water in excess, was found to be approximately independent of pressure (Figs. 9 and 10). These results are in fair agreement with the theory, as the ratio of the equilibrium constant for the most volatile component to the equilibrium constant of water, at a fixed concentration value, is only slightly dependent on pressure in the range from 10-76 cm. Hg.[13]

It may be remarked that the theory is not yet suitable to predict the absolute values of the heat flux maxima in binary mixtures in comparison with the values in the less volatile pure component, unless the validity of the condition (7) is questioned. A more complete theory must be capable of calculating the factor F from Equation (8) as

* The larger number of nuclei active on the same area of heating surface in binary mixtures at certain concentrations was actually observed (section 1.2.2.4.3), and can also be found by extrapolation from Figs. 3 and 6, when the maximum of nucleate boiling in the curves for 4.1% wt of M.E.K. and 1.3% wt of 1-butanol respectively are compared with the maximum in the curve for water. A second favourable fact is that the average frequency of bubble formation increases with decreasing bubble size;[4] compare the footnote on page 12 1.2.1.1 and Figs. 12-1 and 12-3.

TABLE 2. *Water*. Maximum nucleate boiling heat flux data at atmospheric and higher pressures (Fig. 15). T_c = corrected boiling temperature, measured with mercury thermometer. T_p = boiling temperature at pressure p, according to vapour pressure Table .[5]

First stainless-steel boiling vessel						*Second stainless-steel boiling vessel*					
p	$\left(\frac{q}{A}\right)$ max.	film-boiling or burn-out	T_c	T_p	$T_p - T_c$	p	$\left(\frac{q}{A}\right)$ max.	film-boiling or burn-out	T_c	T_p	$T_p - T_c$
ata	cal. sec.$^{-1}$ cm.$^{-2}$		°C	°C	°C	ata	cal. sec.$^{-1}$ cm.$^{-2}$		°C	°C	°C
1.01	16.20	f	100.7*	—	—	1.03	17.22	f	100.6*	—	—
1.04	15.04	f	101.2*	—	—	1.03	20.81	f	100.7*	—	—
						1.03	19.34	f	100.4*	—	—
1.85	20.69	f	112.5	117.2	4.7	1.03	18.36	f	100.7*	—	—
2.73	25.15	f	128.8	129.7	0.9	1.03	17.27	f	101.1*	—	—
2.74	27.16	f	127.4	129.8	1.4	1.03	18.68	f	100.6*	—	—
3.08	28.93	f	131.8	133.8	2.0	1.03	17.98	f	101.2*	—	—
3.38	27.12	f	130.8	137.0	6.2						
4.05	32.94	f	139.5	143.4	3.9	4.28	34.40	f	141.5	145.3	3.8
4.58	33.37	f	141.1	147.8	6.7	5.03	35.44	f	148.0	151.3	3.3
4.58	35.93	f	144.4	147.8	3.4	5.20	26.94	f	150.6	152.6	2.0
4.84	39.51	f	144.3	149.9	5.6	5.30	31.47	f	151.4	153.3	1.9
4.90	36.55	f	148.3	150.4	2.1	5.60	31.03	f	153.3	155.4	2.1
4.98	35.41	f, b	148.2	151.0	2.8	7.73	43.06	f	164.2	168.2	4.0
6.65	49.49	b	158.2	162.1	3.9	10.65	56.38	b	177.5	181.8	4.3
9.78	50.70	b	177.3	178.1	0.8	12.05	35.50	f	185.6	187.3	1.7
						18.33	38.35	f	207.7	207.1	−0.6
						18.98	56.19	f	207.9	208.8	0.9
						19.45	75.11	b	208.4	210.0	1.6
						20.30	42.26	f	212.7	212.1	−0.6
						20.40	67.44	b	208.7	212.4	3.7
						20.45	58.64	f	210.1	212.5	2.4
						20.48	58.53	b	211.6	212.6	1.0
						24.05	56.87	f	218.5	220.9	2.4
						32.28	59.57	f	235.2	236.9	1.7
						35.93	62.45	f	243.2	243.0	−0.2
						35.93	67.74	b	243.2	243.0	−0.2
						48.73	81.95	b	257.0	261.1	4.1

*A slight superheating ΔT of the boiling liquid can be concluded from these data, in agreement with accurate measurements of Jacob and Fritz[7]

TABLE 3. *Water-ethanol*. Maximum nucleate boiling heat flux data at higher pressures (Fig. 16). T_c = corrected boiling temperature, measured with mercury thermometer. T_p = boiling temperature of water at average pressure p, according to vapour pressure table.[5] The data for water have been derived from Table 2 (Fig. 15).

T_c	p	Wt. % ethanol	$\left(\frac{q}{A}\right)$ max.	film-boiling or burn-out
°C	ata		cal. sec.$^{-1}$ cm.$^{-2}$	
First stainless-steel boiling vessel				
$T_p = 151.0$	*4.99*	*0.*	*32.80*	
142.4	4.93	5.37	57.50	b
137.2	5.00	10.54	64.98	b
132.1	4.94	19.98	72.51	b
130.8	4.86	20.47	74.99	b
129.6	4.98	28.83	72.26	b
124.1	5.04	51.81	57.99	b
125.1	5.18	95.58	17.90	f
$T_p = 178.0$	*9.77*	*0.*	*44.65*	
166.0	9.83	7.43	82.24	b
154.8	9.53	19.98	97.30	b
155.0	9.81	28.83	85.95	b
154.4	9.91	51.81	79.30	b
Second stainless-steel boiling vessel				
$T_p = 213.4$	*20.80*	*0.*	*60.70*	
201.4	23.18	18.70	89.15	b
195.1	21.68	23.83	123.74	b
189.1	21.33	48.73	118.15	b
185.3	22.33	68.80	68.19	f
166.3	15.50	95.58	17.11	f
$T_p = 255.9$	*44.70*	*0.*	*79.50*	
241.5	47.23	18.70	129.40	b
224.8	45.03	31.79	172.65	b
225.4	44.73	41.56	143.10	b
208.8	41.83	68.80	99.00	f

TABLE 4. *Water-1-propanol*. Maximum nucleate boiling heat flux data at higher pressures (Fig. 17). T_c = corrected boiling temperature, measured with mercury thermometer. T_p = boiling temperature of water at average pressure p, according to vapour pressure table.[5] The data for water have been derived from Table 2 (Fig. 15).

T_c	p	Wt. % 1-propanol	$\left(\frac{q}{A}\right)$ max.	film-boiling or burn-out
°C	ata		cal. sec.$^{-1}$ cm.$^{-2}$	
First stainless-steel boiling vessel				
$T_p = 150.9$	*4.97*	*0.*	*32.80*	
143.6	4.95	3.96	69.41	b
141.7	4.95	5.50	77.25	b
140.3	5.01	7.01	79.13	b
136.7	5.00	9.87	82.59	b
134.8	4.94	12.79	72.81	b
134.1	4.99	16.38	77.36	b
133.6	4.99	20.13	78.74	b
134.0	4.97	34.03	68.10	b
$T_p = 177.1$	*9.57*	*0.*	*44.30*	
161.5	9.51	9.87	88.69	b
162.4	9.68	12.79	97.36	b
161.1	9.51	16.38	107.64	b
159.1	9.58	34.03	85.56	b
Second stainless-steel boiling vessel				
$T_p = 217.9$	*22.70*	*0.*	*62.70*	
205.4	23.73	18.59	100.00	b
193.8	19.90	33.19	119.46	b
203.1	24.03	37.60	132.62	b
199.8	23.13	51.72	101.36	b
$T_p = 254.3$	*43.57*	*0.*	*78.80*	
234.1	44.73	19.96	130.46	b
230.7	45.03	29.89	175.58	b
232.5	45.73	39.86	163.53	b
215.9	41.43	54.65	117.25	b
216.8	40.93	80.07	20.12	f

TABLE 5. *Water-1-butanol*. Maximum nucleate boiling heat flux data at higher pressures (Fig. 18). T_c = corrected boiling temperature, measured with mercury thermometer T_p = boiling temperature of water at average pressure p, according to vapour pressure table.[5] The data for water have been derived from Table 2 (Fig. 15).

T_c	p	Wt. % 1-butanol	$\left(\frac{q}{A}\right)$ max.	film-boiling or burn-out	T_c	p	Wt. % 1-butanol	$\left(\frac{q}{A}\right)$ max.	film-boiling or burn-out
°C	ata		cal. sec.$^{-1}$ cm.$^{-2}$		°C	ata		cal. sec.$^{-1}$ cm.$^{-2}$	
First stainless-steel boiling vessel					*Second stainless-steel boiling vessel*				
$T_p = 137.1$	*3.39*	*0.*	*27.40*		$T_p = 208.0$	*18.70*	*0.*	*58.30*	
129.9	3.38	2.56	65.52	b	194.2	19.53	9.24	94.46	b
122.3	3.41	5.27	81.00	b	175.3	16.38	11.29	110.20	b
124.6	3.38	9.19	63.76	b	178.6	16.93	12.54	101.36	b
$T_p = 150.3$	*4.90*	*0.*	*32.60*		193.9	18.93	17.23	117.46	b
147.2	4.94	1.00	54.04	b	203.5	22.03	24.46	105.30	b
145.7	4.90	1.89	59.50	b	193.3	18.90	33.70	110.46	b
143.6	4.93	2.56	70.89	b	198.8	20.73	50.30	75.06	f
143.2	4.93	3.18	66.77	b	193.4	18.85	59.30	33.88	f
136.1	4.97	5.27	76.98	b	193.2	19.38	70.84	20.41	f
134.4	4.93	7.05	86.47	b	195.1	19.20	81.54	20.86	f
133.0	4.88	9.19	90.49	b	190.3	16.98	91.89	19.37	f
133.8	4.80	11.63	87.11	b	219.0	16.60	100	11.85	f
131.1	4.97	16.83	64.66	b	$T_p = 254.3$	*43.66*	*0.*	*78.95*	
134.1	4.88	23.29	70.55	b	249.4	46.33	9.74	102.78	b
134.2	4.86	69.86	18.59	f	239.9	45.43	16.83	152.47	b
134.7	4.81	81.25	18.84	f	244.4	46.13	23.74	143.43	b
140.0	4.84	89.31	15.30	f	233.3	40.13	28.32	154.52	b
145.4	4.88	93.30	13.97	f	225.6	40.93	32.26	154.97	b
148.3	4.97	95.57	13.70	f	230.6	44.03	50.30	96.83	f, b
158.1	4.93	100	12.54	f	229.9	42.63	70.05	20.21	f
$T_p = 178.0$	*9.76*	*0.*	*44.80*						
164.5	9.96	2.56	77.69	b					
160.2	9.88	7.05	91.12	b					
160.3	9.93	9.19	113.03	b					
162.3	9.46	11.63	102.42	b					
164.9	9.58	16.83	95.76	b					

TABLE 6. *Water-1-pentanol.* **Maximum nucleate boiling heat flux data at higher pressures (Fig. 19).** T_c **=corrected boiling temperature, measured with mercury thermometer.** T_p **=boiling temperature of water at average pressure** p**, according to vapour pressure table.[5] The data for water have been derived from Table 2 (Fig. 15).**

T_c °C	p ata	Wt. % 1-pentanol	$\left(\frac{q}{A}\right)$ max. cal. sec.$^{-1}$ cm.$^{-2}$	film-boiling or burn-out
First stainless-steel boiling vessel				
T_p = *138.3*	*3.51*	*0.*	*27.70*	
129.6	3.51	2.00	82.80	b
T_p = *151.1*	*5.00*	*0.*	*32.90*	
145.7	4.96	0.96	57.24	b
143.7	4.93	1.90	65.54	b
135.9	4.99	2.43	89.04	b
136.1	5.03	2.96	88.66	b
139.6	5.05	4.57	79.23	b
135.9	5.07	9.24	68.04	b
T_p = *177.8*	*9.72*	*0.*	*44.60*	
165.5	9.73	1.21	70.67	b
163.9	9.88	2.24	95.58	b
161.3	9.71	3.06	115.11	b
165.5	9.71	5.30	95.72	b
167.3	9.56	9.24	91.75	b
Second stainless-steel boiling vessel				
T_p = *252.7*	*42.43*	*0.*	*78.15*	
248.3	44.43	4.87	122.30	b
242.3	38.83	5.99	124.92	b
244.8	40.23	7.30	97.40	b
244.1	45.83	10.36	126.25	b
243.1	42.28	15.88	156.57	b
248.1	47.68	15.88	148.44	b
233.8	36.18	21.85	134.94	b
255.7	52.53	22.64	153.84	b
243.0	44.18	29.65	142.16	b
244.9	43.93	50.62	56.72	f
226.0	40.55	78.60	18.95	f
245.1	38.93	94.97	13.91	f
260.5	36.03	100	9.40	f

TABLE 7. *Water-acetone.* **Maximum nucleate boiling heat flux data at higher pressure (Fig. 20).** T_c **=corrected boiling temperature, measured with mercury thermometer.** T_p **=boiling temperature of water at average pressure** p**, according to vapour pressure table[5]. The data for water have been derived from Table 2 (Fig. 15).**

T_c °C	p ata	Wt. % acetone	$\left(\frac{q}{A}\right)$ max. cal. sec.$^{-1}$ cm.$^{-2}$	film-boiling or burn-out
First stainless-steel boiling vessel				
T_p = *150.7*	*4.95*	*0.*	*32.80*	
139.0	4.93	4.71	61.63	b
129.1	4.88	8.83	72.43	b
122.8	4.97	12.76	80.37	b
117.2	5.06	18.30	76.15	b
116.5	4.82	24.78	75.46	b
111.5	5.04	44.15	72.95	b
T_p = *178.8*	*9.94*	*0.*	*45.10*	
165.9	9.93	4.71	78.13	b
158.4	9.93	12.76	92.77	b
155.7	9.93	20.19	93.18	b
148.3	9.98	44.15	78.44	b
Second stainless-steel boiling vessel				
T_p = *212.3*	*20.35*	*0.*	*60.26*	
196.1	19.90	10.42	95.80	b
200.2	24.28	20.40	122.39	b
187.7	20.83	30.16	120.06	b
182.6	20.60	49.15	119.24	b
175.6	19.30	64.73	89.12	f, b
171.2	19.03	80.27	46.71	f
170.5	18.48	100	10.65	f
T_p = *254.1*	*44.37*	*0.*	*79.35*	
240.7	46.93	10.42	153.27	b*
244.8	48.53	10.42	168.16	b*
224.7	43.53	30.16	149.94	b
233.2	46.03	40.04	156.25	b
225.9	41.73	49.15	156.31	b
225.2	45.23	64.73	104.47	f
207.8	42.53	80.27	28.60	f
202.3	40.43	100	6.31	f

* *Contamination of heating surface due to a heat decomposition of the acetone.*

a function of liquid composition for the binary systems investigated. Only in this way can absolute values of bubble size be obtained; consequently an attempt can then be made to calculate the ratios of the heat flux maxima in comparison with the value for a pure component. The wetting of the surface may also be of importance in this respect.[6] It is satisfactory, however, that the effect of higher maxima obtained in binary mixtures containing an extremely volatile component, appears to be present independent of the constitution of the heating surface (Fig. 11).

TABLE 8. *Water-M.E.K.* **Maximum nucleate boiling heat flux data at higher pressure (Fig. 21).** T_c **=corrected boiling temperature, measured with mercury thermometer.** T_p **=boiling temperature of water at average pressure** p**, according to vapour pressure table.[5] The data for water have been derived from Table 2 (Fig. 15).**

T_c °C	p ata	Wt. % M.E.K.	$\left(\frac{q}{A}\right)$ max. cal. sec.$^{-1}$ cm.$^{-2}$	film-boiling or burn-out
First stainless-steel boiling vessel				
T_p = *151.1*	*5.00*	*0.*	*32.90*	
141.1	4.90	2.17	60.49	b
136.2	4.83	4.10	67.18	b
132.5	5.13	5.29	72.98	b
127.4	4.99	6.75	87.08	b
128.8	5.13	9.14	87.34	b
125.1	5.03	17.44	69.18	b
T_p = *177.6*	*9.66*	*0.*	*44.50*	
164.0	9.51	2.93	76.31	b
158.6	9.68	5.56	86.54	b
159.0	9.71	7.45	91.15	b
160.4	9.73	9.22	98.55	b
159.0	9.66	11.49	97.30	b
156.1	9.68	17.44	92.98	b
Second stainless-steel boiling vessel				
T_p = *210.1*	*19.50*	*0.*	*59.20*	
202.2	21.80	6.21	81.70	f, b
198.9	22.23	12.90	99.50	b
184.9	17.58	17.77	111.80	b
183.1	18.03	26.95	116.66	b
185.3	18.98	32.53	117.99	b
187.4	20.00	50.66	98.76	f
187.0	20.20	64.66	73.25	f
183.7	19.18	75.41	32.00	f
183.3	18.38	93.50	13.19	f
198.2	18.65	100	10.33	f
T_p = *253.1*	*42.70*	*0.*	*78.35*	
240.1	46.93	17.77	154.07	b
231.9	41.13	32.53	158.34	b
216.9	40.03	64.66	80.16	f
217.4	33.78*	100	7.88	f

* *This value was not taken into account for the calculation of the average pressure (42.70 ata).*

TABLE 9. *Water-ammonia.* **Maximum nucleate boiling heat flux data at higher pressure (Fig. 22).** T_c **=corrected boiling temperature, measured with mercury thermometer.** T_p **=boiling temperature of water at average pressure** p**, according to vapour pressure table.[5] The data for water have been derived from Table 2 (Fig. 15).**

T_c °C	p ata	Wt. % ammonia	$\left(\frac{q}{A}\right)$ max. cal. sec.$^{-1}$ cm.$^{-2}$	film-boiling or burn-out
First stainless-steel boiling vessel				
T_p = *150.3*	*4.90*	*0.*	*32.60*	
133.4	4.85	3.99	44.97	f, b
119.5	4.93	7.82	55.36	f
105.3	4.91	11.37	71.39	b
91.0	4.91	16.13	76.81	b
69.4	4.91	25.00	76.30	b
Second stainless-steel boiling vessel				
T_p = *217.2*	*22.43*	*0.*	*62.45*	
177.3	23.13	12.5	100.70	b
140.5	21.73	25.00	117.49	b

1.2.2.4.3. *Photographs of vapour bubbles.*

In order to illustrate the smaller size of vapour bubbles, released from the same heating surface in binary mixtures in comparison with the less volatile pure component, the photographs (Fig. 12) for the system water-M.E.K. have been included. These photographs were taken with the aid of electronic flash light (0.001 sec.). Figs. 12-1 and 12-2 show the increasing size of vapour bubbles in water with diminishing pressure; Figs. 12-3 and 12-4 show this effect for 4.1% wt of M.E.K. Figs. 12-1, 12-3 and 12-5 show that the smallest size of vapour bubbles occurs in 4.1% wt of M.E.K. at atmospheric pressure (compare with Fig. 7). Figs. 12-6 and 12-5 show the increasing number of active nuclei with a higher temperature difference between the heating surface and the liquid at atmospheric pressure (compare with Fig. 3).

An increasing average frequency of bubble formation on a nucleus with decreasing bubble size can also be concluded from Figs. 12-2 and 12-1 for water at different pressures, and from Figs. 12-1 and 12-3 for 4.1% wt of M.E.K. in comparison with water (compare sections 1.2.1.1 and 1.2.2.4.2).

621-52: 66.012

FREQUENCY RESPONSE ANALYSIS IN PROCESS CONTROL—PART II*

Controller response characteristics, matching controllers with plants, optimum settings and experimental methods are examined

by K. GOITEIN, A.M.I.E.E., A.M.I.Mech.E.

Frequency Response of Controllers

Controllers can generally be considered as amplifiers producing a power output from a comparatively small deviation signal. Since the purpose of a controller is corrective action, its phase shift is basically 180 degrees with additional phase advance or phase lag according to the type of controller action. A proportional controller has no phase shift other than the basic 180 degrees, and its gain is equal to the proportional control factor (or the reciprocal of the proportional band width). In a polar diagram in which the polar vector length represents the controller gain and its angle with the positive x-axis the phase shift, the proportional control vectors lie entirely along the negative x-axis. They are independent of frequency. In considering integral and derivative actions, it is assumed that these are additional to the proportional action and only the additional gains and phase shifts are given. (The gains given here are to be multiplied with the proportional control factor to obtain overall gain.)

Integral action produces a phase lag given by

$$\dagger \tan \psi = \frac{1}{\omega S} \quad \ldots . (17)$$

and a gain of

$$G = \sec \psi \quad \ldots . (18)$$

where S is the integral action time constant.

Derivative action produces a phase advance given by

$$\tan \psi = \omega R \quad \ldots . (19)$$

and a gain of

$$G = \sec \psi \quad \ldots . (20)$$

where R is the derivative action time constant.

In a three-term controller having proportional integral and derivative action, the phase lag is given by

$$\tan \psi = \frac{1}{\omega S} - \omega R \quad \ldots . (21)$$

which becomes a phase advance if negative. The gain is again

$$G = \sec \psi \quad \ldots . (22)$$

Fig. 6 shows a vector diagram illustrating the response of a three-term controller of unit proportional control factor; this can easily be extended to cover any proportional band by simply changing its scale. In the diagram, $O - n = -1$ represents the unit proportional vector, $O - A$ the proportional plus derivative vector for $\omega =$

$$\omega = \frac{2}{R};$$

$O - B$ the same for

$$\omega = \frac{1}{R};$$

$O - C$ the proportional plus integral vector for

$$\omega = \frac{1}{S};$$

$O - D$ the same for

$$\omega = \frac{1}{2S}.$$

For representing three-term action, the proportiona derivative and integral vectors are added. Thus, $O - q$ represents the control vector for unit proportional band, $\omega R = n - m$, and $\frac{1}{\omega S} = m - q$. For proportional gain $O - N$ and integral and derivative actions as above, the control vector is represented by $O - Q$.

This applies naturally only to a controller which conforms to the idealised theoretical equation

$$\Theta = -\mu\left(R\frac{d\theta}{dt} + \theta + \frac{1}{S}\int \theta dt\right) \quad \ldots . (23)$$

Commercially-available controllers often deviate from this law considerably. For accurate treatment, therefore, the frequency response of a controller must be evaluated theoretically or by experiment.

In Equations (17) to (23), μ, R and S denote effective values of the proportional control factor, the derivative action time and the integral action time respectively. These values are not necessarily identical with the corresponding control settings due to the presence, in most commercial three-term controllers, of the "interaction factor", generally a function of the ratio of the derivative and the integral time constants. If the control settings are desig-

* *The first part of this article was published in the December, 1958, issue, page 663.*

† *It is regretted that an incorrect symbol for the phase shift has appeared throughout this article. This should have been ϕ as has been used in the diagrams accompanying the article.*

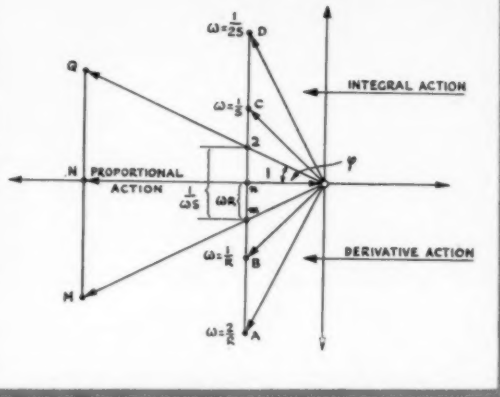


Fig. 6. Vector diagram of frequency response of three-term controller.

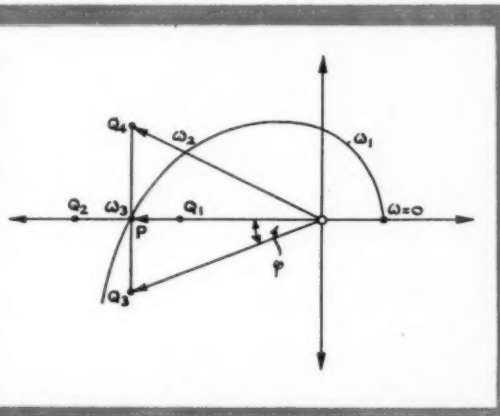


Fig. 7. Superimposed plant and controller diagram.

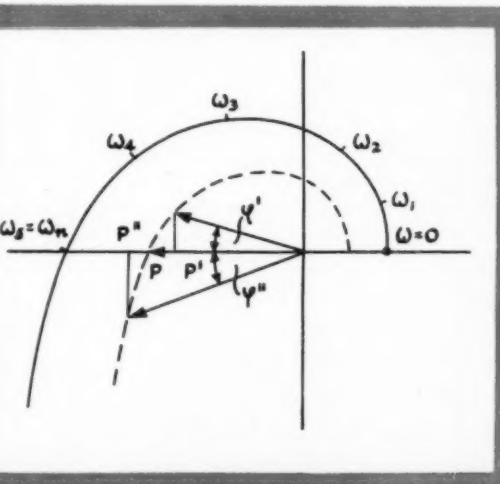


Fig. 8. Undamped (full) and damped (dotted) polar response diagram of plant and construction of "optimum" control vector.

nated by m, r and s and the interaction factor by f, the effective values are given by:

$$\mu = m.f \qquad \ldots.(24a)$$

$$R = \frac{r}{f} \qquad \ldots.(24b)$$

$$S = s.f \qquad \ldots.(24c)$$

The interaction factor is always unity when one or two control terms are used; it is a function of r/s which is inherent in the design of the controller. For many, but by no means all, types of controller it is given by:

$$f = 1 + 2\frac{r}{s} \qquad \ldots.(25a)$$

for other types it is:

$$f = 1 + \frac{r}{s} \qquad \ldots.(25b)$$

The ratio of the effective time constants R/S is, as can easily be shown, a function of the ratio of time settings r/s which has a maximum value. In the case where Equation (25a) applies, this maximum value is:

$$(R/S)_{max} = \tfrac{1}{8} \text{ for } r/s = \tfrac{1}{2} \qquad \ldots.(26a)$$

In the case of Equation (25b) it is:

$$(R/S)_{max} = \tfrac{1}{4} \text{ for } r/s = 1 \qquad \ldots.(26b)$$

The significance of this is that, with these types of controller, increasing the derivative time setting beyond a certain proportion of the integral time setting does not increase the phase advance of the controller and, therefore, does not improve its stabilising effect, as will be further explained in the next chapter.

Matching the Controller to the Plant

A closed-loop control system becomes unstable if, for an overall phase shift (of controller and plant) of 360 degrees, the overall gain is greater than or equal to unity. Since both gain and phase shift are functions of frequency, stability conditions can be studied with the aid of frequency-response diagrams. Perhaps the simplest method is a superimposition of the frequency-response diagrams of the plant (as shown in Fig. 5) and that of the controller (Fig. 6).

Fig. 7 shows how this can be done. Let curve D represent the frequency-response diagram of the plant. With proportional control only, i.e., 180 degrees controller phase-shift, hunting or instability will occur at frequency ω_3 if the controller gain is equal to, or in excess of, the plant attenuation $O - P$ at this frequency, that is, the frequency at which the plant lag is 180 degrees. For a controller gain of $O - Q_1$ the plant will be stable, for a controller gain of $O - Q_2$ it will be unstable. If $O - Q_3$ represents the response vector for a proportional plus derivative controller of the same proportional gain $O - P$ the system will be stable since, at the phase angle of the controller 180 degrees plus ψ, the controller gain is smaller than the plant attenuation. On the other hand, the addition of integral action (controller response vector $O - Q_4$) will make the system hunt at a lower proportional gain.

Generally, the system will be stable if the controller response vector lies inside the plant response locus. Since the controller response vector lies always on the left half of the plane (Fig. 6), it can be seen from an inspection of the response loci of various types of plant shown in Fig. 5 that a single-stage RC plant can never be unstable; that a two-stage RC plant cannot be unstable with proportional or proportional plus derivative control, however large the controller gain; that instability can occur with any combination of controller modes if three or more RC stages or a DV lag are present. In fact, the "controllability" of a plant deteriorates with the addition of any time lags and particularly DV-lags, as can be seen from Fig. 5. A pure DV-lag, fortunately rare in practice, can produce hunting

at any controller setting if the controller gain exceeds unity.

Optimum Control

In this way, the frequency response locus of a plant, however complex, defines the limits of possible stable control settings. The best possible settings, however, depend on what the control system is expected to achieve and on the relative importance of particular response characteristics, such as recovery time after a disturbance, maximum deviation, offset, etc. The optimum-control setting is usually a compromise between conflicting requirements, and no universally applicable rules can be set up for it. Certain definitions are useful in this connection.[12]

Natural frequency: The frequency at which the plant oscillates when proportional control only is employed. This frequency is given by the intersection point of the plant response locus with the negative X-axis.

Characteristic attenuation: The attenuation at the natural frequency.

Offset: The permanent deviation, due to a load change, of a proportional control system. In a linear system, it is proportional to the load change and inversely proportional to the controller gain.

Subsidence ratio: The ratio of two consecutive amplitudes of a damped oscillation.

Deviation reduction factor: The ratio of the potential deviation due to a sudden change in the system to the actual maximum deviation of the controlled variable. The potential deviation for any particular disturbance is the deviation which would be approached exponentially in the absence of control action; the controller reduces this deviation by a factor called deviation reduction factor. It can be shown that this factor is approximately equal to the controller gain.

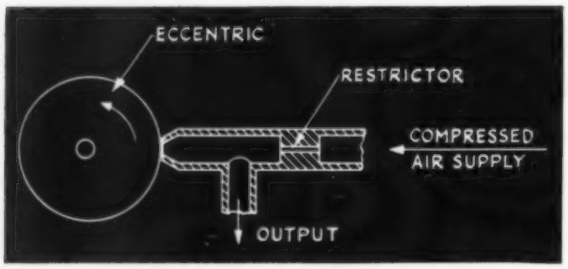


Fig. 9. Pneumatic oscillation generator.

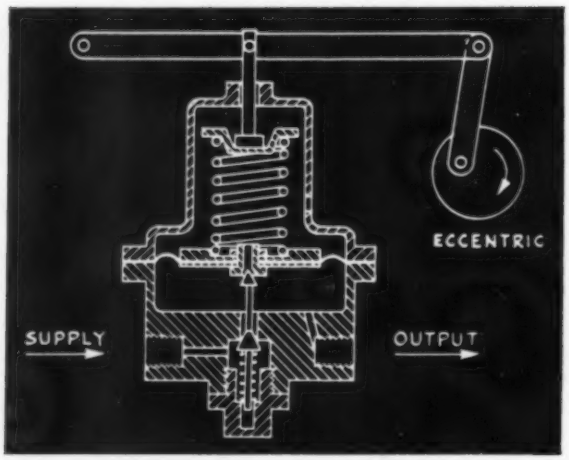


Fig. 10. Pneumatic oscillation generator.

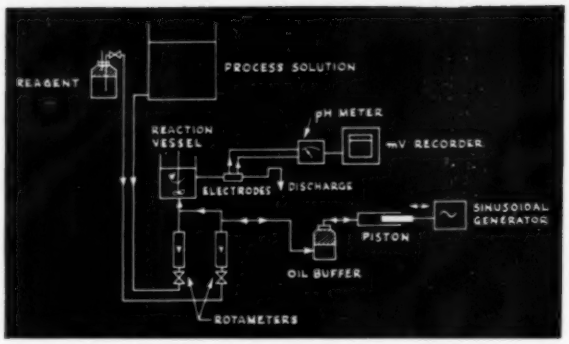


Fig. 11. Experimental arrangement for measuring the frequency response characteristics of a liquid-liquid neutralisation process. (With acknowledgments to Prof. H. Kramers.)

In general terms it is desirable for optimum control that the offset should be as small as possible, and the subsidence ratio and the deviation reduction factor as large as possible. As far as controller settings are concerned, this means the highest possible controller gain (lowest possible proportional band) consistent with stability and tolerable subsidence ratio. In other words (referring to the frequency response diagram, Fig. 7), the controller response vector must be as large as possible, provided it remains safely inside the plant response locus. The necessary safety margin of stability is a matter of opinion, but it has been generally accepted that a subsidence ratio of $e:1$ (or about $3:1$) is a reasonable compromise.

If the undamped response function of a plant is known, the damped response function for a given subsidence ratio can be calculated by substituting $-\alpha + j\omega$ for $j\omega$. Approximate graphical methods of constructing the damped response locus from the undamped locus have been devised. The rigorous treatment of damped response is involved and outside the scope of this article. For a subsidence ratio of $e:1$, the following formulæ have been calculated:

The attenuation for a single RC lag of time constant T is

$$A = \left[\left(1 - \frac{\omega T}{2\pi}\right)^2 + \omega^2 T^2\right]^{\frac{1}{2}} \quad \ldots.(27)$$

The phase lag is not affected by the damping. For several time lags, the attenuations can be multiplied.

The attenuation for a DV-lag of magnitude L is

$$A = e^{\frac{\omega L}{2\pi}} \quad \ldots.(28)$$

The problem of optimum controller settings can now be tackled in the following way:

(a) From the plant response locus, the damping locus corresponding to an acceptable subsidence ratio, say $e:1$, is constructed. This represents the locus of the controller vector.

(b) The second step is to find the controller vector, on this locus, of the highest possible gain or, since the gain increases with the phase advance, of the highest possible phase advance. Fig. 8 shows how this can be done. For proportional control, the control vector is obviously given by $O - P$. For proportional plus integral control the choice of the optimum controller settings is somewhat more difficult. Integral control produces, as has been explained above, a time lag. It is therefore undesirable from the point of view of tight control and stability. Integral action, i.e. $\frac{1}{\omega S}$, should therefore be as small as possible, or integral action time S as large as possible, provided

the purpose of integral control, which is the elimination of offset, is achieved. It has been shown that this condition is obtained if S equals the natural period of the plant, i.e., $\frac{2\pi}{\omega_n}$. Once S has been determined, the phase angle follow from Equation (17). It is:

$$\psi = \tan^{-1} \frac{1}{2\pi} \qquad \ldots . (29)$$

which is approximately 9 degrees. As can be seen from Fig. 8, the proportional gain $O - P$, is smaller than that which can be employed with proportional control only. If derivative control is added, its time constant R should be such as to produce the maximum possible phase advance, i.e., $R = \frac{1}{4} S$, or $\frac{1}{3} S$, according to the type of controller used. With non-interacting controllers, the derivative time can be increased considerably. The phase angle follows from Equation (21) and the proportional gain factor $(O - P'')$ is seen to be increased by the addition of derivative control.

It is to be noted that the interaction of derivative and integral action severely limits the extent to which derivative action can be usefully employed for improving and stabilising control. Some controllers, pneumatic as well as electronic, have been designed which eliminate interaction with the effect that proportional gain and derivative time are only limited by the adjustment facilities of the controller. The higher cost of these non-interacting controllers can, however, not always be justified on practical grounds. Derivative control has certain undesirable side effects, such as over-sensitivity to high-speed random disturbances, which make its application to the fullest possible extent of doubtful value.

Experimental Frequency — Response Analysis

For experimental frequency-response analysis, a sinusoidally variable signal is injected into the process and input and output are simultaneously recorded. Preferably, input and output variables are so chosen that they can be recorded in the same units, e.g., psi, lb/hr, °C, but where this is not possible, equivalent values have to be taken, making use of the concept of potential values as explained above.

The determination of potential value relationships is not always easy and, wherever possible, they should be measured directly. In the case of temperature control, for instance, it may be possible to measure the temperature attained at a certain point of the process when pneumatic pressure is applied to a regulating valve, thus correlating temperatures and pneumatic pressures. In a chemical process it may similarly be possible to correlate p_H values to changes of flow ratios of process fluid and reagent. In inherently unstable processes, the effects of such experiments for evaluating potential values may be quite prohibitive since, in the absence of automatic control, the process may get out of hand. In such cases, methods of extrapolation, purely theoretical considerations, or a combination of both approaches are often helpful.

The equipment required for experimental frequency-response analysis consists essentially of a variable frequency oscillation generator, instruments for measuring and recording simultaneously, preferably on one chart, the input and output variables and transducers, if required, to convert these variables into conveniently recordable forms. Recorders and transducers are conventional, commercially-available instruments, and will, therefore, not be dealt with here. Oscillators, however, suitable for the variables and frequencies of process control applications, are usually specially designed and made for this purpose. A few examples of such devices will be described in brief outline.

Oscillation Generators

A simple device for generating an oscillating pneumatic pressure is shown diagrammatically in Fig. 9. A variable-speed eccentric controlling the outlet gap of a nozzle with restricted air supply produces an output pressure varying almost sinusoidally. This device, although perhaps not very accurate, is quite adequate for many applications.

Fig. 10 shows a somewhat more elaborate device for the same purpose. This is a conventional spring-loaded pressure regulator with a crankshaft attachment for varying the spring tension sinusoidally.

The problem becomes somewhat more difficult when variables other than air pressures have to be oscillated. As an interesting example, KRAMERS[16] describes an experimental arrangement for varying the addition of a reagent to a process fluid sinusoidally in a liquid-liquid neutralisation process. This is reproduced in Fig. 11, which is self-explanatory.

An electrical signal can be varied by means of a cam-operated rheostat or by a rotary auto-transformer at low frequencies or by conventional electronic oscillators at higher frequencies.

Non-linear Systems

In view of what has been said about non-linearities, it is advisable to keep the amplitudes of signal variations small, say not more than about 5 to 10% of the maximum (which, incidentally, enables these tests to be carried out without undue disturbance of the process or plants in operation), and to take frequency response measurements at several levels of the variable, say at 20, 40, 60, 80 and 100% of the maximum. If the response characteristics at these values vary considerably, frequency-response analysis has to be applied individually for all values of practical importance. Different control settings may be required for different desired values; but it will often be possible to arrive at a compromise controller setting which will produce stable and satisfactory control for all values. This ability to deal with non-linear systems in a comparatively simple way is one of the major advantages of experimental frequency-response analysis as against the purely theoretical treatment of control problems.

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CAPITAL COSTS OF PROCESS VESSELS, HEAT EXCHANGERS AND DISTILLATION EQUIPMENT*

by B. POLLARD, B.Sc., E. V. WOOD, Eng.Dip., and J. CARTER, A.M.Inst.B.E.†

Few figures have hitherto been published on British plant costs. Here the authors present up-to-date information on such equipment and, in addition, suggest "short-cut" factors for various materials of construction and for various operating pressures.

IT is a hazardous business to put forward in public cost estimates for equipment in which there is such a high degree of competition as exists in the process plant fabrication industry today. It should be understood, therefore, that the figures presented represent an average for the British fabricating industry. One must, of course, in assembling such figures, try to take into account not simply the cheapest price but a normal price that one would expect to pay consistent with good quality workmanship and reasonable delivery. Within this framework the figures should be reasonably accurate for the situation as it now stands in Britain.

Fabrication costs for vessels of different types and various materials of construction are given below.

Vessels—Mild Steel—Fabrication Costs

Atmospheric storage tanks—	
Rectangular	£130/T large sizes
„	£180/T small „
Cylindrical	£180/T large „
„	£300/T small „
Low-pressure Vessels, Stills, etc.	
	£200/T large „
	£400/T small „

(Also depending on class of workmanship)

Process Vessels

Fabricating cost varies considerably with type of internals, complexity, pressures, class of workmanship, etc., but would be in the range of	£240/T to £450/T

Vessels—Stainless Steel—Fabrication Costs

Atmospheric cylindrical storage	£750/T to £1500/T
Pressure vessels	£900/T to £1750/T
Process vessels	£1000/T to £2200/T

(Remarks same as for mild-steel vessels)

Vessels—Aluminium—Fabrication Costs

Atmospheric cylindrical storage	£650/T to £1400/T
Pressure vessels	£850/T to £1700/T
Process vessels	£950/T to £2200/T

(Remarks same as for mild-steel vessels)

Relative Costs

Material	*Factor*
Mild Steel	1.0
Aluminium	2.0 to 2.5
Stainless Steel	2.5 to 3.0

Heat Exchangers

In addition to the data presented in the graphs, it should be noted that for T.E.M.A.-type heat exchangers variation in tube length has a great effect on the cost per sq. ft, as follows:

16 ft length	factor 1.0
8 ft „	„ 1.5
4 ft „	„ 2.5

The influence of material is shown below.

Material	*Factor*
All mild steel	1.0
Non-ferrous on tube side	1.2 large sizes
„ „ „ „	1.35 small sizes
Stainless steel on tube side	2.0 large sizes
„ „ „ „ „	2.5 small sizes
All stainless steel	3.0 to 3.5

In all cases the price per sq. ft for ¾-in. o.d. tubes is slightly higher, say 2%, than for 1-in. o.d.

Cost Factors for Alternative Pressures (T.E.M.A. type)

Working Pressures	*Factor*
150	1.0
300	1.1
400	1.2
600	1.4

For U-tube exchangers the price per sq. ft can be taken as equal to that for fixed tube plate type.

Distillation Columns

It is almost impossible to give comprehensive cost data on distillation columns owing to the very large number of different types of plates which are now being used.

For smaller jobs where packed columns are employed, the question of cost is simply one of simple multiplication of the basic cost of the ring-pack times the number required. These rings are produced in such large quantities that the price does not vary very much with quantity. Approximate prices, which, of course, will depend on quantity, are of the following order:

Porcelain rings

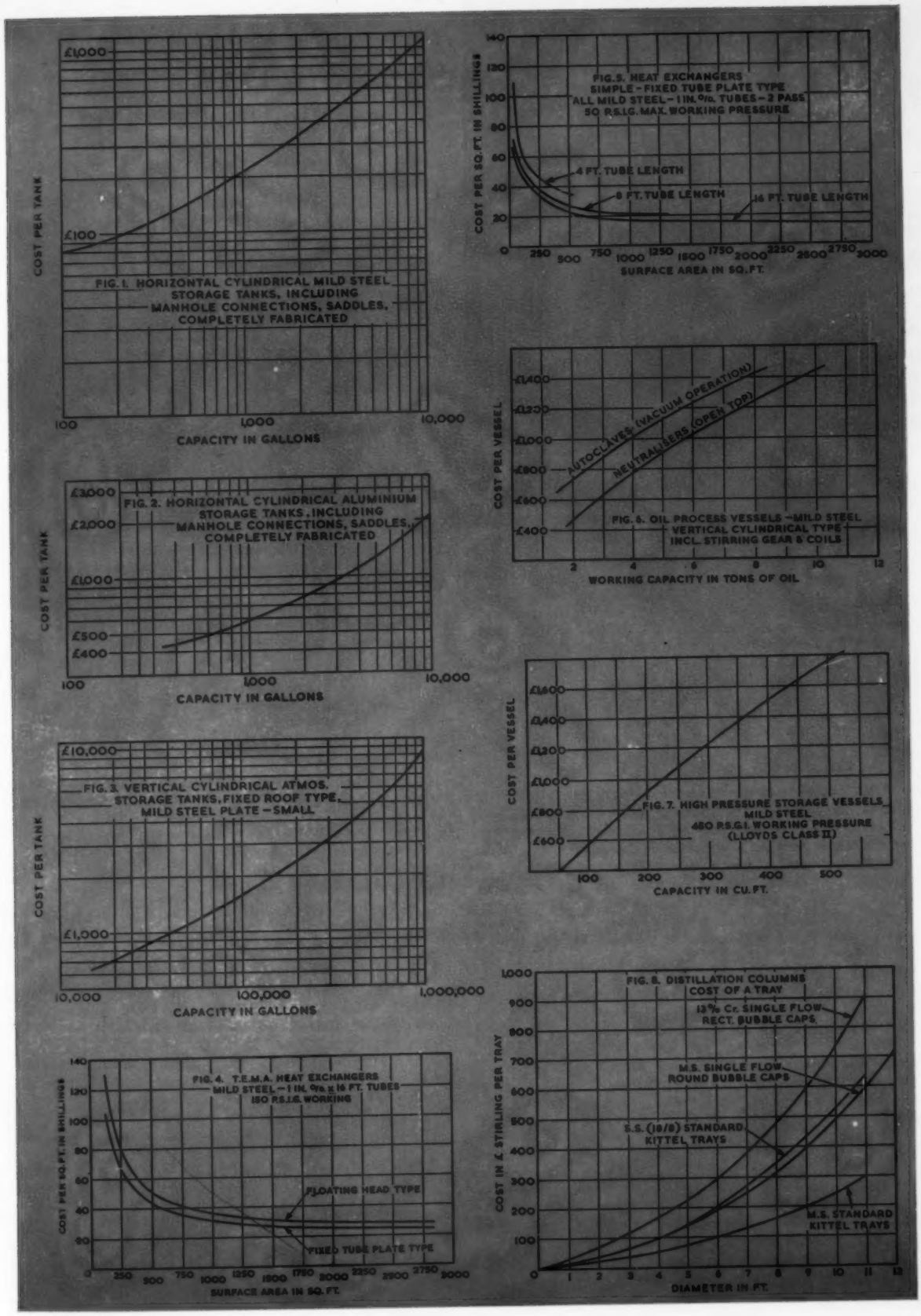
2 in.	15s. per cu. ft
1½ in.	18s. „ „ „
1 in.	25s. „ „ „
½ in.	67s. „ „ „

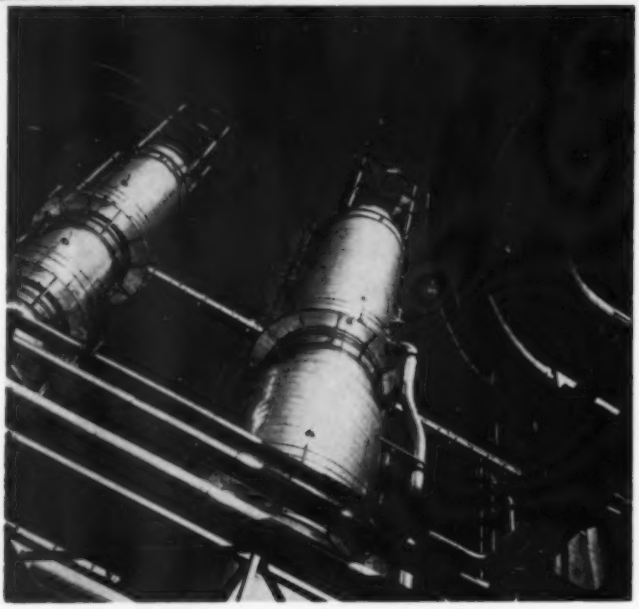
If these figures are taken as a base of 1.0, the factor for mild steel is 2 and for stainless steel about 10.

The curves presented in Fig. 8 show costs of bubble-cap trays in terms of column diameter for mild steel and 13% chrome steel. For 18/8 steel the price for 13% chrome steel should be increased by about 20%. Figures are also presented in Fig. 8 for one of the newer type of plates, the Kittel plate, on the same basis. These are given as absolute figures and, of course, should not be used to make direct comparisons of cost for a given duty. The specific throughput of each type of plate must be considered in order to do this; the cost of the newer types of plate with high specific throughput will be reduced even further than is shown by the graph.

* *This paper was presented at the Symposium on Chemical Engineering Economics organised by the Graduates and Students Section, Institution of Chemical Engineers.*

† *Constructors John Brown Ltd., London, W.2.*


£1,000
£100
COST PER TANK
FIG. 1. HORIZONTAL CYLINDRICAL MILD STEEL STORAGE TANKS, INCLUDING MANHOLE CONNECTIONS, SADDLES, COMPLETELY FABRICATED
100
1,000
10,000
CAPACITY IN GALLONS
COST PER SQ. FT. IN SHILLINGS
FIG. 5. HEAT EXCHANGERS SIMPLE - FIXED TUBE PLATE TYPE ALL MILD STEEL - 1 IN. O/D. TUBES - 2 PASS 50 P.S.I.G. MAX. WORKING PRESSURE
4 FT. TUBE LENGTH
8 FT. TUBE LENGTH
16 FT. TUBE LENGTH
SURFACE AREA IN SQ. FT.
£3,000
£2,000
£1,000
£500
£400
FIG. 2. HORIZONTAL CYLINDRICAL ALUMINIUM STORAGE TANKS, INCLUDING MANHOLE CONNECTIONS, SADDLES, COMPLETELY FABRICATED
CAPACITY IN GALLONS
£1400
£1200
£1000
£800
£600
£400
COST PER VESSEL
AUTOCLAVES (VACUUM OPERATION)
NEUTRALISERS (OPEN TOP)
FIG. 6. OIL PROCESS VESSELS - MILD STEEL VERTICAL CYLINDRICAL TYPE INCL. STIRRING GEAR & COILS
WORKING CAPACITY IN TONS OF OIL
£10,000
£1,000
FIG. 3. VERTICAL CYLINDRICAL ATMOS. STORAGE TANKS, FIXED ROOF TYPE, MILD STEEL PLATE - SMALL
10,000
100,000
1,000,000
CAPACITY IN GALLONS
£1600
£1400
£1200
£1000
£800
£600
COST PER VESSEL
FIG. 7. HIGH PRESSURE STORAGE VESSELS MILD STEEL 450 P.S.G.I. WORKING PRESSURE (LLOYDS CLASS II)
100
200
300
400
500
CAPACITY IN CU. FT.
FIG. 4. T.E.M.A. HEAT EXCHANGERS MILD STEEL - 1 IN. O/D x 16 FT. TUBES 150 P.S.I.G. WORKING
FLOATING HEAD TYPE
FIXED TUBE PLATE TYPE
COST PER SQ. FT. IN SHILLINGS
SURFACE AREA IN SQ. FT.
FIG. 8. DISTILLATION COLUMNS COST OF A TRAY
13% Cr. SINGLE FLOW RECT. BUBBLE CAPS
M.S. SINGLE FLOW ROUND BUBBLE CAPS
S.S. (18/8) STANDARD KITTEL TRAYS
M.S. STANDARD KITTEL TRAYS
COST IN £ STIRLING PER TRAY
DIAMETER IN FT.



66.048.3

A most unusual camera view of two distillation columns at the M.E.C. Refinery at Shell Haven. The smaller column employs grid-type trays.

THE DESIGN OF GRID-TYPE TRAYS

by H. E. EDULJEE, Ph.D., A.M.I.Chem.E.

After considering recent work on hydraulics of grid trays, the author suggests a design method based on the loading point

A PREVIOUS issue of BRITISH CHEMICAL ENGINEERING[1] described the use of grid-type trays in distillation and reviewed some recent Russian work on this subject. HOBLER and KRUPICZKA[2] have published data on the hydraulics of grid trays in a Polish journal and a review of their work would be of interest to English readers.

HOBLER and KRUPICZKA studied trays of 196 mm (7.7 in.) diameter. The slot-width ranged from 1.85 mm to 4.0 mm and slot area/column cross-sectional area from 6.53% to 14%. The pitch of the slots was 25 mm and the plate thickness 2 mm in all cases. Only the air-water system was studied. When the pressure-drop across a plate is plotted (on log-log co-ordinates) against increasing gas rate at constant liquid rate, the plot can be divided into three straight lines. At low gas rates, the liquid falls quietly through the slots. At higher gas rates, liquid builds up on the plate and froths and the pressure-drop gas-rate curve shows a sharp upward trend. At still higher gas rates the liquid is blown off the plate and the pressure drop increases very rapidly with small increase in gas rate. The two breaks in the curve may be called the "loading" point and the "flooding" point by analogy with packed columns. These two points can also be obtained experimentally[2] by varying the liquid rate at constant gas rate. Their data cover the loading point but do not go up to the flooding point.

The authors[2] measured the pressure drop at various water and air rates, as well as the froth height and what they call the "reduced" height: this height appears to be same as the hydrostatic head due to the build-up of the liquid on the plate. They correlate their data thus:

$$h = 1.85 \times 10^{-6}\ v_L^{0.4}\ v_G^{1.5}\ s^{-1.1} \qquad \ldots.(1)$$

$$\text{for values of } v_L^{0.5} \cdot v_G^{1.5}\ h^2 < 8.6 \times 10^{-3} \qquad \ldots.(2)$$

The limiting value given by Equation (2) is apparently the loading point. They have tried to generalise Equation (1) by introducing viscosity and density terms:

$$\frac{h.g}{v_L.v_G} = 2.5 \times 10^{-4} \left(\frac{v_L\, s.\rho_L}{\mu_L}\right)^{-0.6} \left(\frac{v_G.s.\rho_G}{\mu_G}\right)^{0.5} \left(\frac{l}{s}\right)^{1.5} \qquad \ldots.(3)$$

$$\text{or } Eu = 2.5 \times 10^{-4}\ (\mathrm{Re}_L)^{-0.6}\ (\mathrm{Re}_G)^{0.5} \left(\frac{l}{s}\right)^{1.5} \qquad \ldots.(4)$$

where l is the standard length of the slot taken as 1 m. Equation (3) represents their data within ±30% in the range

$$\mathrm{Re}_L^{0.5}\ \mathrm{Re}_G^{1.5} \left(\frac{h_f}{s}\right)^2 < 1 \times 10^8 \qquad \ldots.(5)$$

In Equations (1) to (5):

h = hydrostatic head, m;
h_f = height of froth, m;
s = slot width, m;
ρ = fluid density, kgm/m³;
v = fluid velocity through slot, m/sec.; and
μ = fluid viscosity, kgm/m-sec.

Subscripts L and G refer to water and air respectively.

The data cover the range: v_G: 3-10; v_L: 0.0009-0.04; s: 1.85-4 mm.

The relationship between h and h_f is given by:

$$\frac{h_f}{4\sqrt{v_o}} = 2.35\ (h - 0.01)^{0.9} \text{ for } h < 0.05\text{m} \qquad \ldots.(6a)$$

and

$$\frac{h_f}{4\sqrt{v_o}} = 1.23\ (h - 0.01)^{0.7} \text{ for } h > 0.05\text{m} \qquad \ldots.(6b)$$

where v_o is the superficial vapour velocity, m/sec.

A scrutiny of the data shows that for all practical purposes $h_f \simeq 2.0h$. The pressure drop, expressed as height of water, is found to be equal to the hydrostatic head. The pressure drop of the dry plate is 0.5 to 5.0 mm water and that of the wet, drained plate is 9 to 15 mm water.

The authors[2] suggest the following design method:

(a) For a given vapour throughout (V_G m³/sec.) assume a value for v_o and calculate the diameter of the column.

Dr. Eduljee *is with National Peroxide Ltd., Sewree Cross, Bombay-31, India.*

(b) Assume a value for the ratio slot area/column area and calculate v_G and v_L through the slots. The value of v_G should be less than 7m/sec. or "flooding" will occur.

(Reviewer's comment: sample calculations show that this velocity refers to the "loading" point as defined in this review.)

(c) Assume a value for h and calculate s from Equation (1). Alternatively, assume s and calculate h.

(d) The total length of the slots is then calculated and from this the pitch of the slots.

(e) Knowing h, and v_o, the froth height, h_f, can be calculated from Equation (6). (Alternatively estimate h_f from $h_f = 2.0\ h$.) The plate spacing is now decided upon.

(f) Pressure drop is estimated from $\triangle p \simeq h$. The value of h should not be less than 24 mm.

(Reviewer's comment: HOELER and KRUPICZKA'S work is on the air-water system only; hence the effect of fluid properties is not known. The attempt to generalise the data by means of Equation (3) is probably not justified. The data apply only to a particular tray pattern, as the effect of pitch of slots and plate thickness was not studied.)

Alternative Design Method

The method discussed above involves assuming values for v_o, slot-area/column-area ratio, and h (or s). Also, while the assumed value of v_o may be suitable from the point of view of tray hydraulics, its effects on mass-transfer efficiency is not taken into account. By analogy with packed towers, it may be assumed that best mass-transfer efficiency is obtained when the tray is operating at the loading point. Grid trays should therefore be designed to work at the loading point. Assuming from Equation (2) that the loading point is given by:

$$v_L^{0.5}\ v_G^{1.5}\ h^2 = 8.6 \times 10^{-3} \qquad \ldots.(7)$$

and substituting for h from Equation (1) and re-arranging:

$$\frac{L}{G} = 1.695 \times 10^7 \left(\frac{\rho_L}{\rho_G}\right) \frac{s^{2.5}}{v_G^{4.5}} \qquad \ldots.(8)$$

in metric units, where L and G are the mass rates of water and air respectively. Substituting $\rho_L = 62.4$ and $\rho_G = 0.074$ and converting to convenient British units, Equation (8) may be written as:

$$\frac{L}{G} = 3.41 \times 10^8 \frac{s^{2.5}}{v_G^{4.5}} \qquad \ldots.(9)$$

and Equation (1) becomes:

$$h = 2.72 \times 10^{-3}\ (v_L)^{0.4}\ (v_G)^{1.5}\ s^{-1.6} \qquad \ldots.(10)$$

In Equations (9) and (10), v is in ft/sec.; L and G in lb./hr; s in in. and h in in. of water. These equations apply only to the tray patterns of the authors[2] and to the air-water system.

Sample Calculations

Design a tray to handle 20,000 lb./hr of air and 100,000 lb./hr of water. Assume a slot width of 4.0 mm (0.1575 in.) will be used, with pitch = 25 mm.

$$L/G = 100{,}000/20{,}000 = 5.0$$
$$s = 0.1575$$

Substituting in Equation (9), $v_G = 19.7$ ft/sec. This is the gas velocity through slots at the loading point.

Gas volume throughput = $V_G = 20{,}000/(0.074 \times 3600) = 75.2$ cu. ft/sec.

Total slot area = 75.2/19.7 = 3.82 sq. ft.

For 4-mm slots at 25 mm pitch, the ratio slot area/column area is 0.14. Hence column area = 3.82/0.14 = 27.3 sq. ft and column diameter = 5.9 ft.

Liquid volume throughput = 100,000/(62.4 × 3600) = 0.445 cu. ft/sec.

Hence $v_L = 0.445/3.82 = 0.1163$ ft/sec. through slots.

From Equation (10), h is calculated to be 1.94 in. water.

$$\triangle p \simeq h = 1.94 \text{ in. water}$$

$$\text{Froth height} = h_f \simeq 2h = 3.87 \text{ in.}$$

The tray spacing must be some multiple of the froth height. Assuming that it is twice froth height, tray spacing = 7.74 in., or say 8 in. In deciding upon the plate spacing, entrainment must be taken into account. There is no published correlation for entrainment from grid trays, but data of SIMKIN *et al.*[3] suggest that it is not more than for sieve plates. Using correlation of HUNT *et al.*[4] for sieve plates, it is calculated that for the above tray the entrainment will be 0.061 lb. water per lb. air or 9.7 moles water per 100 moles air. The tray spacing is hence satisfactory.

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[1] Anon. *Brit. Chem. Eng.*, 1957, **2**, 544.
[2] Hobler and Krupiczka. *Chemia Stosowana*, 1957, **1**, 105.
[3] Simkin, *et al. Chem. Eng. Prog.*, 1954, **50**, 565.
[4] Hunt, *et al. A.I.Ch.E. Jour.*, 1955, **1**, 441.

Kestner's Golden Jubilee

THE attainment by a firm of its golden jubilee under the chairmanship of the founder is a rare event which Kestner Evaporator & Engineering Co. have just been privileged to celebrate, and the occasion has been marked by the publication of a commemorative 100-page book liberally illustrated. The company's growth is inextricably linked with the work and foresight of its founder, JAMES ARTHUR REAVELL, a pioneer of the Chemical Engineering Group of the Society of Chemical Industry and of the Institution of Chemical Engineers, and a past chief officer of both organisations. Many readers of the golden-jubilee book will wish that MR. REAVELL's own personal contribution to it had been longer, for he has modestly limited himself to the beginnings of the company. If brief, his record, however, is written with colour and enlivened with anecdotes and with revealing glimpses of immortal personalities of the chemical engineering profession in Britain and elsewhere.

REAVELL wished to become a chemist, he tells, but through the influence of a strict father he found himself in 1889 a student apprentice to a firm of electrical engineers—an experience which gave him a wide view of engineering, as that branch was not so "departmentalised and cut and dried" as it later became. It was EDGAR DUCHE, who had industrial plants in North America and on the Continent, who introduced him to the Frenchman PAUL KESTNER—an Alsatian of great personal charm and technical capacity—and who suggested that the two men should link in business. REAVELL, it was proposed, should take over the Empire rights (except Canada) of the Kestner evaporator, and KESTNER insisted that his name should be included in the title of the company to be formed. As in any case REAVELL could not readily use his own family name because it had been given by his brother to a compressor company, the organisation known as the Kestner Evaporator & Engineering Co. Ltd. came into being in 1908. The story of its expansion from modest offices in Queen Victoria Street with its staff of REAVELL, an engineer and a secretary is told partly in the chairman's foreword and partly in the main body of the book. The main section is divided into chapters which deal with technical developments in chemical engineering—evaporation, drying, and handling, Keebush and other resistant materials, complete plant installations, etc.—as the company has seen them. The review closes with a note on the company's interest in fostering education.

OSLO CHEMICAL ENGINEERING EXHIBITION

Electro-metallurgy and fish processing figured prominently in Norway's first ever chemical plant exhibition

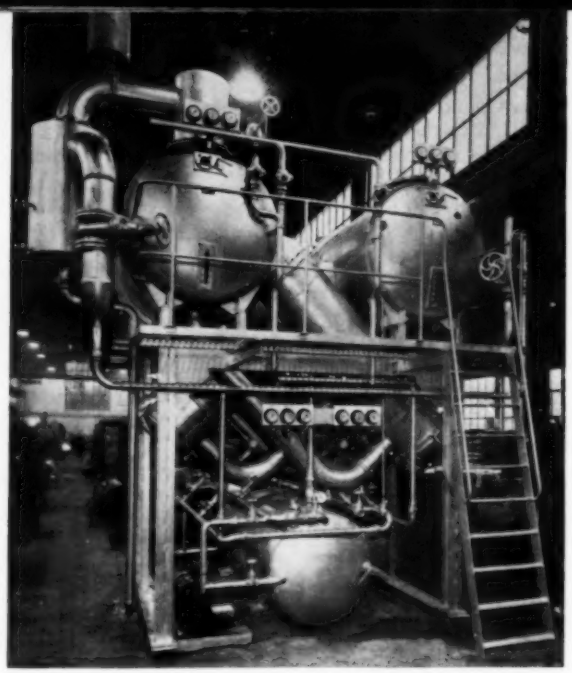


Fig. 1. In the workshops of A/S Moglestue: plants of this kind recover valuable feeding material from fish industry wastes.

NOT the least unusual feature of this exhibition was its venue, the grounds of the historic medieval Akershus castle which, with its slender old towers, greets visitors to Norway who sail up the fjord into Oslo port. In view of the nature of Norwegian industry, which in addition to valuable mineral deposits has ample supplies of cheap power—the cost of a unit is less than a tenth of a penny—it was not surprising that processes and equipment devoted to ore preparation, to electrochemical and electro-thermal technology occupied an important position in the exhibition; and in this respect this exhibition differed from other engineering exhibitions held recently in Britain and in Europe.

The exhibition itself was not without its historical aspects, for to be seen at the stand of Elektrokemisk A/S was the original electric cannon of PROF. K. BIRKELAND and SAM EYDE. With this apparatus the two pioneers were able to prepare successfully for the first time synthetic nitrogen derivatives from the air, and their equipment was the forerunner of the powerful Norwegian nitrogen industry. The early work was pioneered by Elektrokemisk A/S, and subsequently the industry was greatly expanded by Norsk Hydro-Elektrisk Kvaelstofaktieselskab, who, also, were prominent among the exhibitors.

The Elektrokesmisk A/S stand, incidentally, was one of the most interesting on view; particularly the examples of thermoelectric equipment shown. There was, for example, a model of the latest type of 45,000-amp. aluminium furnace equipped with Søderberg electrodes which are now fitted with vertical contact studs. The latest type of closed calcium carbide furnace which employs Søderberg electrodes was shown also in model form, this particular example representing a 10,000-kVA unit equipped with a water-cooled, stainless-steel cover and with a rotating furnace. Furnaces of this type, but of 39,000 kVA capacity, have been or are about to be installed at plants in the British Isles. Another interesting model was a further Søderberg electrode, this time fitted with a new pneumatic slipping arrangement. The Elektrokemisk company have developed a number of other electric smelting furnaces including the world's largest ferrosilicon furnace which is rated at 24,000 kVA, as well as a 20,000-kVA pig-iron furnace.

Norske Hydro, like many of the other processing firms

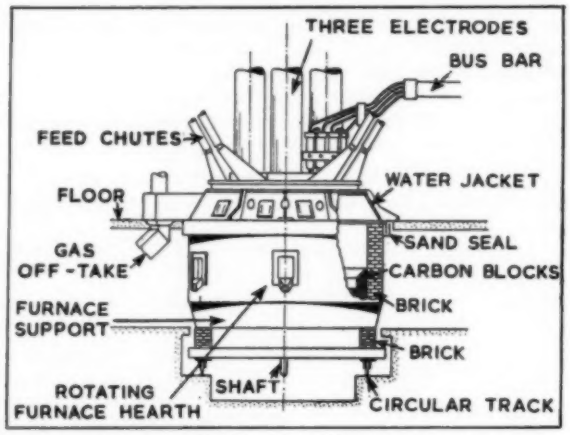


Fig. 2. The new 39,000-kVA Elkem carbide furnace.

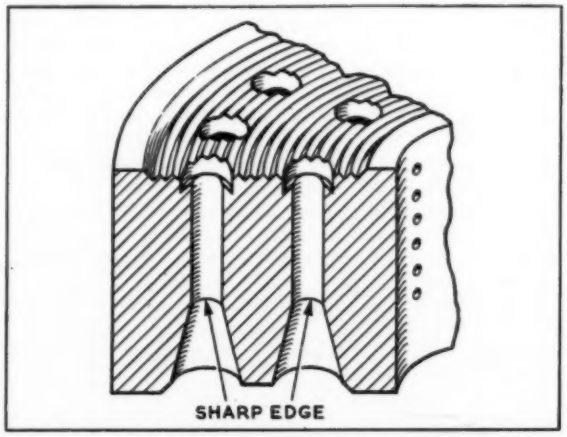


Fig. 3. Shown by Le Carbone Lorraine: part of a new hydraulic acid absorber. The sharp edge helps the formation of a stable liquid film.

who exhibited, were at something of a disadvantage in comparison with manufacturers of equipment. Nevertheless, a bright display of products, plant, photographs and diagrams gave the visitor an insight into the wide range of technology practised by this company. Nitrates, liquid ammonia, chlorine, soda, rare gases, such as argon, neon, helium, krypton and zenon, magnesium metal, and the Norweign brand of PVC, Norvinyl, were among the products whose manufacture was depicted on this stand.

Apart from the number of products shown on the stand of Norske Hydro, electrolytic techniques were displayed by Siv. J. C. Falkenberg on behalf of the Krebs Organisation. This company engineers the Kuhlmann contact sulphuric-acid plants and manufactures the Krebs cell which is widely used in Norway. Krebs have played an important part in the development of the mercury cell by means of which chlorine, hydrogen and caustic alkali to a concentration not possible by other cells can be produced. The Krebs cell, although it assumes more electrical energy than the diaphragm cell, produces stronger caustic soda and makes evaporators unnecessary. Despite this, so we learned from MR. FALKENBERG, diaphragm cells are also offered by this company for small plants processing ample supplies of steam, and where small amounts of chloride can be tolerated in the product.

An impressive feature of other engineering exhibitions has been the display of fabricated equipment, and it was disappointing to find so little of this kind at this exhibition. In fact A/S Moglestue had the field to themselves, and for the most part the medium of display for sizeable equipment was photography. To this there were a few exceptions. For example, Liberg A/S of Oslo, as well as showing the self-same, single-screw Nauta mixer which appeared at Olympia, had on view a newer twin-screw, twin-cone construction of 10 m^3 total capacity. This machine, provided with a 20-hp motor, can produce a homogeneous mixture from a 5 m^3 batch of powdered solids in less than 3 min.

The A/S Moglestue display was a varied one and included a stainless-steel, multi-pass tubular heat exchanger, and an interesting piece of fabrication in the shape of a water-cooled stainless-steel cover for a carbide furnace. Also presented was a model of the latest design of stickwater plant developed by Limvann A/S. Stickwater is obtained from the treatment of herring, fish and whale and for some time was looked upon as a nuisance to be disposed of. It does contain, however, valuable protein material and its recovery has proved to be an economic process. In essence, the process is a multi-stage vacuum evaporation, and a feature of the plants is the ease with which increased capacity can be added. Usually the stickwater is evaporated to 35% concentration of solids and this concentrate is mixed with wet-pressed cake and dried to give a feeding material which differs little from normal fish meal.

A new process for the manufacture of dehydrated cod livers from cod-liver residue, shown by Sea Foods A/S, reflected the efforts that have been made in Norway in recent years to put the cod-liver-oil industry on a rational basis. In this process raw material and solvent are treated in cooking vessels in which simultaneous distillation of water and the extraction of oil from the liver tissue takes place.

The dehydrated material and solution of oil in solvent are transferred to an evaporator for removal of solvents. The miscella is transferred to a fat kettle and the remaining solvent is removed by direct steam distillation under vacuum. Finished dehydrated cod-liver is discharged from the evaporator and the finished oil is recovered by evaporating the remaining solvent (see Fig. 4).

New Type Absorber

Shown by the Norwegian branch of La Société le Carbone-Lorraine, in conjunction with Robert Jenkins Ltd., was a new type of absorber for dissolving hydrochloric or hydrofluoric acid in water (see Fig. 3). This resembles the well-known Poly-bloc heat exchanger, but with a difference in shape for the vertical channels. At the upper end of each vertical channel is a ledge which helps the liquid to flow film-wise over the surface. The cylindrical section terminates in the diffuser-like exit, the junction of the two forming a sharp edge which plays a very important part in establishing the liquid film. It enables, moreover, a stable film to be formed at very low rates of liquid flow. This feature confers upon the absorber the ability to produce strong acid when the throughput of hydrochloric-acid gas becomes greatly reduced through burner failure. This is not possible with packed absorbers unless some of the acid gas is allowed to escape to atmosphere, otherwise if the packings are properly wetted the result is a weak and useless acid. This shortcoming does not exist with the Poly-bloc design of absorber, which has another advantage in its easy removal of heat of solution. It was disclosed at the stand that the now well established heat exchangers can be obtained from R. Jenkins in standard units of up to 530 sq. ft each; exchangers with surfaces

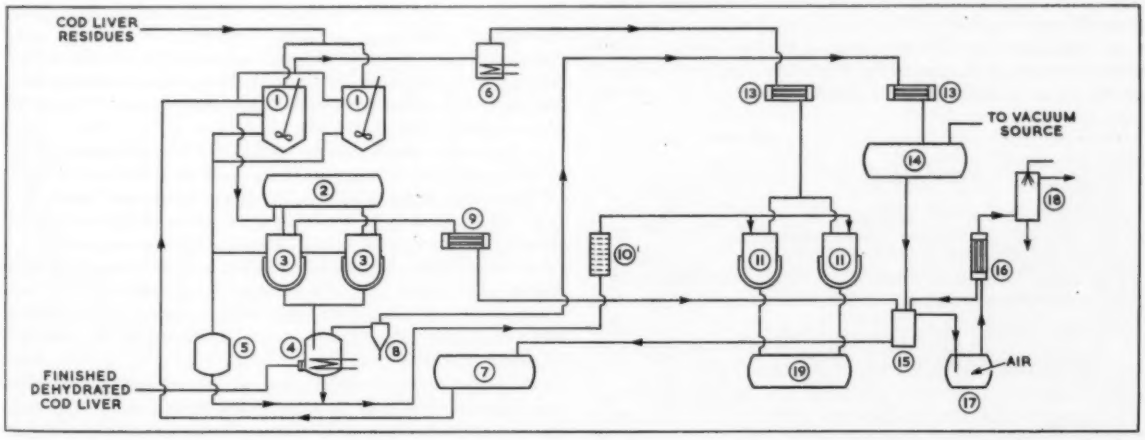


Fig. 4. A/S Sea Foods' process for dehydrated cod liver. 1, slurry tanks; 2, receiver; 3, cookers; 4-12 evaporators; 5, miscella tank; 6, preheater; 7, solvent storage; 8, dust trap; 9-13 condensers; 10, filler; 11, fat kettles; 14, vacuum tank; 15, decanter; 16, vent condenser; 17, air scrubber; 18, scrubber; 19, cod liver oil storage.

greater than this can be manufactured to special order.

Although little was to be seen in the way of heavy crushing machinery, a number of pictorial flow-diagrams were in evidence which illustrated well the magnitude of some Norwegian grinding installations. At the iron-ore plant of A/S Sydvarangen at Kirkenes, for example, the primary gyratory crusher is no less than 54 ft in diameter; it consumes 600 hp and weighs 450 tons. Heavy gearboxes suitable for driving such massive machinery were to be seen. Braathan & Co., of Oslo, displayed B.W.B. double helical gear units capable of transmitting 400 hp, or more, as well as smaller worm gears suitable for a hp range of 0.3 to 50. Vessel agitator drives with fixed and variable ratios were also shown by this company.

The eliminating, for economic reasons, of stone and low-grade ore from the main feed of ore to a crusher, as well as the removal of tramp metal, are problems which found a very convincing solution on the stand of A.S.E.A., where a working model of a novel type of detector was to be seen. In this, inferior or tramp material on a belt conveyor is passed over a coil, and is detected by measurement of the transient change of a tuned oscillator circuit, of which the coil forms a part. In full-scale plants, at a short distance beyond the search coil, a deflector plate can be fitted which is operable electromagnetically or pneumatically through the oscillator unit. Should tramp or rubbish pass over the coil, then the plate will deflect the inferior material into a hopper, returning to its normal position after the material has been discharged.

Instruments Well Represented

Instruments were more abundant than automatic process-control equipment, but a fair show of the latter was made by process-control consultant Ing. Helge Ingeberg with a display of controllers for level, flow and temperature from the Elliott group of companies as well as from Fischer & Porter of the U.S.A. A novel departure was a blackboard used by MR. INGEBERG for demonstrating the principles of automatic-process control.

The German instrument firms were well represented. E. Löchen showed a number of flow-measurement instruments manufactured by Wilh. Lambrecht of Göttingen. One instrument of the pilot-tube type was provided with a rotating cylindrical scale for indicating the velocity; the instrument covers a range of 0.2-5.0 m/sec. and can be supplied with probes of 0.4 m to 1 m in length. These instruments are very sensitive, for gentle exhalation upon the pitot was sufficient to produce movement of the scale. Repeater vane-type anemometers were also shown by the same firm, capable of giving a velocity reading at 6-sec. intervals over a period of 1 min. For temperature measurement Ultrakust GmbH demonstrated an electronic thermometer which uses in the probe a germanium semi-conductor of $\frac{1}{4}$ mm diam. Temperatures in the range −50°C to −450°C can be measured with a lag of less than a second.

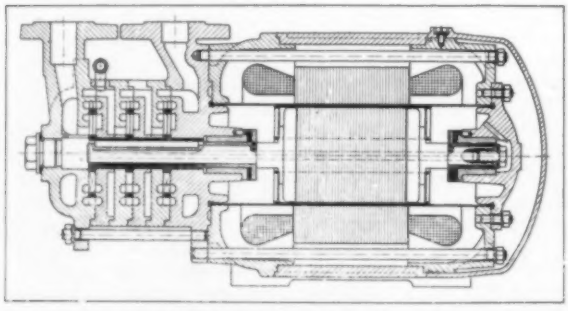


Fig. 5. Canned Rotor pumps have been shown elsewhere in single-stage form. This three-stage Chempump was shown by E. Löchen.

Fig. 6. Other A/S Moglestue products: stainless-steel valves for the food industries complete with O-ring couplings.

Automatic weighing machines were shown by the Norwegian firm of Lindells, whose range includes conventional batch weighers and automatic machines with hopper capacities of up to 4 tons. Electronic bunker level indicators were shown by Caspar Hansen (representing Claudius Peters), one interesting example consisting of a vertically mounted probe, the submergence of which is registered on a remotely-mounted cylindrical scale, either as a fraction of total depth or in any other convenient units. A number of other level instruments were shown by Hansen for indicating when certain limits of depth are reached and for the automatic operation of bunker slides and conveyors.

Lack of Pumps

At occasions of this kind pumps are usually abundant, but this time only a few were in evidence. Among them was an all-glass propeller pump manufactured by Schott & Gena (Mainz). This pump, as shown, was fitted with an interceptor at the pump suction, sufficient to maintain a volume of priming liquid when the pump is shut down. The capacity of this pump is 150 l. per min. against a head of 3 and 270 l. per min. when the head is reduced to 2.5 m. Shown also was a glandless canned-rotor Chempump three-stage centrifugal (Fig. 5) which was to be seen on E. Löchen's stand.

Proportioning pumps with a delivery of less than 0.1 gal./hr are not readily found. Nevertheless, Diesel-Holland (Deha) of Haarlem had such a unit at the exhibition. It was a double-piston, variable-stroke machine capable of generating a delivery pressure of 2800 psi, with a maximum output of 0.34 gph, reducible to 1/100 of this figure by altering the stroke. Other models made by this company will deliver metered quantities of up to 11 gph or more against varying heads.

Among the materials of construction, foremost were the refractory materials, an understandable feature in view of their wide use in the metallurgical industries. The home firm of Borgestad had an array of materials in various shapes in alumina-based refractories such as arch bricks, discs and muffle elements in silicon carbide; while carbon blocks for blast furnace linings, cathode blocks for aluminium reduction cells, insulating bricks and Søderberg electrode paste were the principal exhibits of Société des Electrodes & Refractoire.

As a whole, this exhibition was an interesting one with a generous sprinkling of novelty. Its shortcomings—arising no doubt from the lack of support from some of the larger continental engineering concerns—could not be attributed to its organisers, the Sludreselskapet Norske Industri., whose efforts resulted in a commendable first venture.

66.066.4

by M. E. O'KEEFFE TROWBRIDGE

USE OF THE CENTRIFUGE FOR BREAKING DISPERSIONS

THE paper by MR. E. ATKINSON and DR. D. C. FRESHWATER on the separation of liquid dispersions* comes as a useful review contribution in the specific application of liquid-liquid extraction processes. There may, however, be some danger of certain of the authors' remarks being misleading, if translated in the broader sense of general liquid-liquid separations, particularly in respect of their comments on the use of centrifuges.

In the conclusions, the authors state that the centrifuge does not offer an answer to the breaking of a stable dispersion, and that the mechanism of separation in a centrifuge is simply enhanced gravity settling. That this conclusion is open to criticism may be illustrated by considering some of the many liquid-liquid separations carried out commercially. For example, the recovery of vegetable oil from soapstock is typical of a centrifugal process which requires the concentration of the emulsion, followed by resolution of the concentrated portion. The soapstock is a by-product of vegetable oil refining, resulting from the neutralisation of the free fatty acids in the oil with caustic soda. As the soapstock settles, it carries down with it, mechanically entrained, a certain percentage of free oil. The action of centrifuging not only separates the soapstock; it also squeezes the soapstock to displace the free oil and liberate it from the soapstock mass. This squeezing action is a function of the centrifugal force to which the soapstock is subjected, and is an excellent example of the way in which this centrifuging technique cannot be treated strictly on a basis of sedimentation of particles or droplets through a continuous medium. It also illustrates a case where the tubular bowl high-speed centrifuge has a substantial advantage over the relatively low-speed disc-type centrifuge—an advantage not shown up by the oversimplified consideration of centrifugal sedimentation alone.

There are many other industrial examples of liquid-liquid separation in which the advantage of using a centrifuge is not simply an accelerated separation but a difference in the degree of resolution or emulsion breaking that can be obtained. In some of these cases a third phase —in the form of solids—is present, causing emulsion stabilisation; part of the effectiveness of the centrifuge in resolving emulsions results from separating the solid particles.

Centrifuges contribute to produce results that are unobtainable by other means such as in the resolution of crude petroleum emulsions, the recovery of wool grease from wool scouring liquors, the separation of oils from cotton-waste wash waters. In the centrifugal separation of nitroglycerine emulsion the very small inventory of unemulsified nitroglycerine in the centrifuge, as compared with that in gravity or cyclone separation, results in greatly enhanced safety of operation.

The authors' comments on the relative merits of the high-speed tubular bowl and the disc-type centrifuges were also interesting, but here again it is possible that they might prove misleading if applied in the general sense. Being associated with a company that manufactures both types of centrifuge, I believe that I can speak without commercial bias in this matter. For the practical reasons of simplicity of construction, ease of cleaning, greater centrifugal force, and greater suitability for construction in corrosion-resistant materials, the high-speed tubular-bowl machine is preferred to the disc machine in all except one class of liquid-liquid separation.

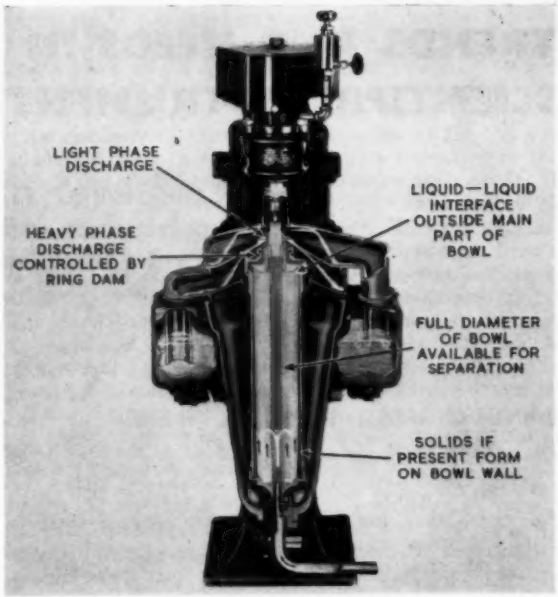

LIGHT PHASE DISCHARGE
HEAVY PHASE DISCHARGE CONTROLLED BY RING DAM
LIQUID—LIQUID INTERFACE OUTSIDE MAIN PART OF BOWL
FULL DIAMETER OF BOWL AVAILABLE FOR SEPARATION
SOLIDS IF PRESENT FORM ON BOWL WALL

Fig. 1. A tubular bowl centrifuge.

The exception lies in the concentration of light-phase emulsions. Examples occur in cream manufacture, latex concentration, and the separation of fat from glue liquors. In these cases the disc bowl appears to perform a function unexplained by conventional separation theory.

A further point in favour of the use of the tubular bowl centrifuge for all other liquid-liquid separation problems is that it can be built in such a way that the liquid interface necessary to maintain the hydraulic seal can be located outside the bowl (see Fig. 1). In this way the whole effect of the bowl can be devoted to separation. This contrasts with the effect in the case of the disc bowl, where the area of the heavy-phase layer is lost to effective separation due to the necessity of maintaining the seal. This feature of the tubular bowl is particularly advantageous where one is especially interested in obtaining maximum capacity of the light-phase material, as in the dehydration of oils.

The authors' assertion that in the tubular-bowl centrifuge "the settling distance must be nearly equal to the radius of the bowl" is also open to question. Tubular bowl units can be built with very thin layer separation where the case warrants this. Moreover, although the settling distance between the discs is small in the disc-type bowl, serious re-entrainment of the heavy-phase liquid and, indeed, of heavy-phase solids (if any are present) takes place in passage through the feed zone.

These notes are offered in the hope that they may be of interest to readers and as a comment on the authors' statement that "Centrifuges, because of the high capital and operating costs, tend to be limited in application in separating liquids to those cases where a very short time of contact is essential and/or the value of the production is exceptional". Such a generalisation must be treated with caution.

Mr. M. E. O'Keeffe Trowbridge *is the managing director of Sharples Centrifuges Ltd., Camberley, Surrey.*

* *British Chemical Engineering*, 1958, **3**, 10, p. 554.

TRENDS AND NEEDS IN SCIENTIFIC INSTRUMENTATION

At the Seventh Annual Convention of the Scientific Instrument Manufacturers Association, short opening talks were given to form a basis for fruitful discussion between user and maker. Below we give summaries of some of these introductions

Oil and Chemicals: The Future

by J. D. Tallantire, B.A., A.Inst.P., Head of the Head Office Group, Control · Instrument Section, Imperial Chemical Industries Ltd., London.

AN INSTRUMENT INSTALLATION as used in the chemical plant comprises:

a measuring unit;
some kind of transmitting system;
an indicator, recorder or other receiving unit;
a controller; and
a control valve or other regulating unit.

Particularly noteworthy aspects of current trends are the development of analysis measuring instruments, of new types of flowmeter and of transducers giving electrical outputs for data-handling systems. Increasing attention is being paid to analytical instruments. As a general rough estimate, chemical analysis might now be said to take 20 minutes. To speed this up, designers often start by mechanising an existing method such as titrimetry or gas analysis by absorption and measuring the volume reduction. Following this stage has been the introduction of gas-liquid chromatography and infra-red analysers which are coming into wide use. For flow measurement there is now some tendency to turn from the widely used orifice plate to such methods as the electromagnetic and the ultrasonic. As part of the wider use of electrical devices, the introduction of strain-gauge load cells for determining contents of storage tanks should be noted.

During this year there has been a big increase in interest in electronic controls, but there is still no electrical valve. Electronic computers are not reliable enough for direct application in process control loops, but it is to be expected that this will be improved; meanwhile, plant and process characteristics are being investigated so that adequate "instructions" for such computers may be framed when they are available. This trend is likely to accelerate the utilisation of the simpler forms of electronic transmitting and control equipment and of scanning and data logging systems. However, for the successful use of an optimising system there are two important requirements:

(1) The user must study the process to determine the effects of the operative factors.
(2) Makers must provide better flowmeters, analytical instruments and transistorised units, while computers must become dependable and certain in operation.

Nuclear Power Plant Instrumentation

by B. H. Stonehouse, B.Sc. (Eng.), A.M.I.E.E., Senior Electrical Engineer, Atomic Energy Division, General Electric Co., Ltd.

TOTAL COST of instrumentation on a single-reactor nuclear-power station is £300,000 excluding the cost of the burst-cartridge-detection equipment. A single spurious reactor shut-down would represent a loss of approximately £10,000 to the generating authority. High reliability of instruments associated with the reactor safety circuit is therefore vital. When the reactor is working at full power, seven out of thirteen trip features in the reactor safety circuit are directly associated with the physical instrumentation. To improve reliability all safety circuit detecting features have been triplicated. Further instruments are used for indication and alarm purposes and good reliability of these is required if the control room staff are not to be fatigued by their maloperation.

At the moment, some safety circuit detectors are more reliable than others, and as a first move a high uniform reliability is required. Unfortunately, there is insufficient information on detectors to enable a statistical assessment of their reliability to be made, and hence a calculation of the amount of extra money which could be afforded for their development.

The instruments requiring development or under development are:

(a) thermocouple trip amplifiers with a long-term stability of $\pm 1°C$ and an accuracy of tripping of $\pm 1°C$;
(b) gas flow measuring devices suitable for working at a statistic pressure of 200 psi and producing negligible pressure losses in a 5-ft gas duct; and
(c) detectors for moisture in CO_2 having a 5 sec. time response and capable of detecting over a range of 100 to 10,000 ppm.

The materials of construction for equipment mounted directly in the reactor coolant gas are limited due to the following considerations:

(a) they should not have a high neutron capture cross-section;
(b) they should not react with the magnesium alloy fuel-element cans to form low-melting point eutectics; and
(c) it should not be possible for them to be carried over on to the fuel element heat-transfer surfaces and, therefore, to reduce the efficiency of heat transfer.

To ensure that these conditions are met, all materials of this nature should be totally enclosed and firmly anchored in the reactor structure. To ensure control of the amount of such materials in the reactor circuit, it is necessary that all components should be thoroughly cleaned and degreased before insertion in the gas circuit.

In a nuclear-power station problems arise in the positioning of the instruments and control gear in the central control room. Controls are required for the reactor, steam-raising units, turbo-alternators and main station switchgear. The main arc of panels for a single reactor could be 30 ft long. Consideration is being given to possible means of reducing the total amount of instrumentation presented to the operator. Data-handling techniques are being employed for the 750 thermocouple measurements associated with the reactor and for the 800 points being scanned every half-hour by the burst-cartridge-detection equipment. Ideas about the amount of data-processing equipment to be used, however, are still very fluid.

Iron and Steel: Future Trends

by W. C. Heselwood, B.Sc., A.Met., F.I.M., Head of Physics, United Steel Companies Ltd.

NEW AND DEVELOPING PROCESSES in the industries include direct reduction of ore, oxygen steelmaking and continuous casting. Electric arc steelmaking is expanding. Nevertheless, the blast furnace and the open-hearth furnace will continue as major tonnage producers, but speeded up with tighter control and better preparation and blending of raw materials. New instruments are needed, including much more rapid chemical analysis. Forming operations will incorporate a wider range of measurements, some linked to automatic control. All processes require more data transmission and much more data collection for computer analysis to achieve good programming and to ascertain the best settings for push-button and automatic controls. Rapid non-destructive testing should extend from fault-finding to the determination of positive properties.

Oil and Chemicals: Plant Instrumentation

by C. W. Munday, B.Sc., A.R.I.C., Section Leader, Instrumentation Department, Distillers Co., Epsom.

IN MODERN CHEMICAL PROCESSES, measurement of the quality of chemical products is growing in importance. Instruments for such purposes are general automatic analysis instruments. Before a fully-automatically controlled chemical plant can be constructed, instruments have to be designed that will automatically measure the quality of the product. At the moment, relatively few reliable plant-tested instruments are available. These include pH meters, infra-red gas analysers and oxygen analysers. It is necessary to draw a distinction between a plant instrument and a laboratory instrument. It is not sufficient to put a satisfactory laboratory instrument into a pressurised case and call it a plant instrument. Reliability and freedom from drift are very important desired characteristics of plant instruments. In addition, the basic units of instruments should be kept as small as possible. Flame-proofing, which involves the introduction of very large thermal inertias, may defeat the object of the measurement. If the measurement is temperature dependent, a trivial adjustment to an instrument with large thermal inertia may mean that the instrument will take 24 hours to stabilise again.

In quality-measuring instruments the problem of getting the sample to the instrument is just as important as that of having an accurate and safe instrument. It is true to say (excluding flue gas problems) that the scientific instrument industry has not considered the problem of the correct design of sampling system. All the work on sampling systems has to be done by the user. Manufacturers of quality-measuring instruments should realise that an instrument may get a bad name for unreliability due to failure of the sampling system.

Standardisation of major components of instruments is very desirable. Could not manufacturers agree to produce a standard range of meters so that different makes were interchangeable? Could not potentiometer recorders be produced in two standard sizes?

Why does the British instrument industry lag behind in the field of quality-measuring instruments? Why do ideas and techniques which originate in this country have to cross the Atlantic or the North Sea before they are put into commercial production? Examples of this kind include the delay in applying TYNDALL's suggestion in 1880 of the use of chopped infra-red radiation analysers for the detection of methane in coalmines. First application of the idea was in the 1930s by Americans, Russians and Germans. Similarly, gas chromatography, developed here by MARTIN and others from 1941 onwards, was used in industry by workers who built their own units, but the first commercial gas chromatograph was produced in the U.S.A.

Manufacturers should supply more adequate technical data sheets on performance of instruments. Drift, reproducibility, absolute accuracy, effects of mains voltage, frequency, altitude, pressure fluctuation and response of instrument to step change should all be clearly indicated. They should also offer service to compare with the best American practice in servicing quality-measuring instruments. This includes a 24-hour reversed-charge telephone service for faults, applicable over the whole of the U.S.A. Another feature is that each instrument is supplied with a numbered detailed photograph of each key point, so that faults can be located by telephone and unnecessary service visits avoided. One progressive instrument manufacturer (who makes a steady profit!) goes so far as to guarantee major units of his instrument against obsolescence. If a substantially different and improved unit is provided, the obsolete unit is exchanged for a new unit and the purchaser pays the difference between the original cost of the obsolete unit and the cost of the new unit.

Closest co-operation between user and manufacturer will result in better and more reliable instruments that are truly fitted for tasks they have to perform. Exchange of ideas is most valuable, and it is to be hoped that this process will continue to expand in the future.

First Computer Exhibition

AT THE WORLD'S FIRST computer exhibition, held at Olympia, London, recently under the auspices of the Electrical Engineering Association and the Office Appliance and Business Equipment Trades Association, 43 manufacturers with factories in Britain showed their latest developments in electronic computer equipment for use in process control and data handling. The trends revealed were towards smaller machines and greater reliability—achieved partly by the use of transistors instead of valves; higher speeds; larger memories; and provision for parallel programming and "sharing" of time so that one machine can undertake several jobs simultaneously. Among the new machines of potential use in process control were the Ferranti PCTC, a prototype, desk-sized, special-purpose computer incorporating transistors and no thermionic valves and designed primarily for the starting up and shutting down of large boilers; Solatron's small Minispace TY 864, 10-amplifier analogue computer; National-Elliott's 802 computer demonstrated as if it were exercising overall control of an industrial process; and Panellit's 600-point temperature scanner set. Details of these and of other pieces of equipment shown will be given in our February issue.

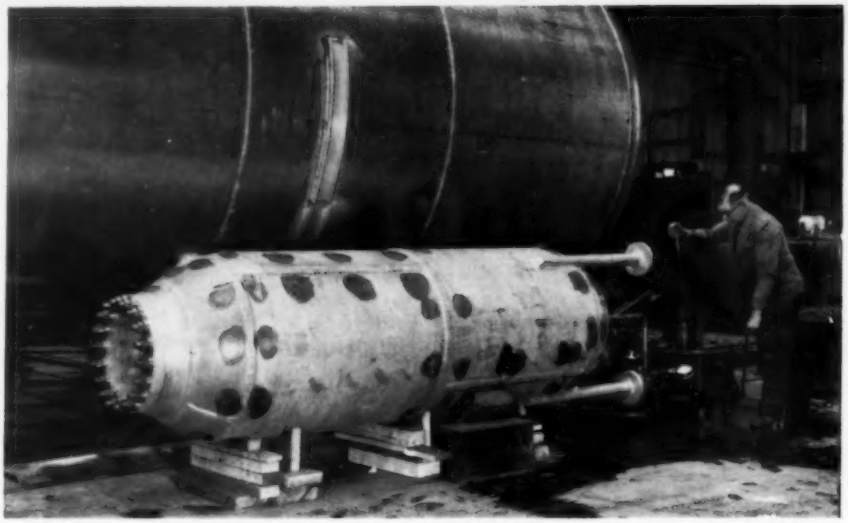


Fig. 1. A liquid oxygen container in NP5/6 under hydraulic test.
(Courtesy A.P.V. and M.O.S., Westcott.)

ALUMINIUM PRESSURE VESSELS SYMPOSIUM*

Codes of Practice for Constructing Pressure Vessels in Aluminium and its Alloys

THE OPENING PAPER, delivered by R. T. ROSE and J. G. YOUNG, reviewed four existing codes. These were the A.S.M.E. boiler and pressure vessel code, 1956, the A.P.I. 1957 code, the S.N.C.T., 1954, and the Swedish boiler and pressure vessel code, 1955. Unfortunately, details of the German code were not available at the time the authors prepared their paper.

The subject-matter was arranged into three sections: (1) Design Aspects; (2) Metallurgical and Testing Requirement; and (3) Observations on the Preparation of a British Code. Design stresses recommendations, joint efficiencies, wall thickness, ends, and such details as reinforcement of openings and flange dimensions were examined. A strong plea was made for the evolution of a rational design procedure which may have to recognise the effects of corrosion fatigue, stress corrosion, high-strain fatigue, creep, excessive plastic deformation and so on. In the discussion, the ability of the material to absorb energy, important to its resistance to fracture, was mentioned as another property which ought to be considered in any code.

Of the other properties, in MR. GOODMAN'S (A.P.V.) opinion, corrosion, proof stress, fatigue range, creep, but not tensile strength, were the most useful guides to the design stress. For mild-steel vessels one practice is to allow the proof stress to be reached, but not exceeded, at a test pressure 1½ times the working pressure. For many years in the case of gas-welded aluminium vessels, working stress of 2 tsi, a test stress of 3 tsi and a joint efficiency of 100% had been used; although the proof stress is less than 3 tsi, there had been no failures of aluminium vessels designed according to this rule. The fatigue range, he thought, would be around 10^4-10^5 and often less.

According to MR. MCNEISH (G. A. HARVEY), an understanding of stress distribution in vessels should be incorporated in any new code. He supported his argument with examples of stress concentration in aluminium pressure vessels. One design which should be avoided had an opening at a part of a vessel where its shape changed. In the same example the supporting legs were attached at points of maximum stress concentration. MR. MCNEISH pointed out also that aluminium is used at temperatures approaching the range at which creep is significant, a point touched upon by MR. LANCASTER, who indicated that the Germans have a short-term creep test which gives a good correlation with long-term behaviour.

Aluminium-base Materials suitable for Pressure Vessel Construction

IN THIS PAPER, MR. E. ELLIOTT (ALUMINIUM DEVELOPMENT CORPORATION) summarised the available information on the physical properties of aluminium and its alloys. These materials fall into three main classes: the pure metal grades, the non-heat-treatable and the heat-treatable alloys. Any may be used in casting or wrought semi-fabricated form; B.S.1490 covers casting alloys, B.S.1470-1477 refer to wrought materials.

Pure aluminium and the non-heat-treatable alloys owe their strength to their composition and to the degree of hardness produced by cold working; aluminium-1¼% Mn alloys and various Al-Mg alloys have a capacity for work hardening which increases with magnesium content. In the case of the heat-treatable alloys, on ageing the precipitation from solid solution of one of the submicroscopic alloying constituents is accompanied by an increase in tensile strength and proof stress and some loss of ductility.

For pressure vessels, corrosion resistance, ease of fabrication and ability to give round joints restrict the choice of material. Pure aluminium (99.5% grade) is widely used; of the non-heat-treatable alloys, the 1¼% Mn alloy (N3) is akin to a slightly stronger form of pure aluminium and the aluminium magnesium alloys N4, N5, N6 and NP5/6 are suitable for pressure vessel construction (see Table 1).

In the heat-treatable alloy groups, alloy H30 is at present the most useful, although another alloy, H9, with lower content of alloying elements, H30, has advantages in the manufacture of tubes and other extrusions. The aluminium-copper-magnesium heat-treatable alloys are difficult to weld and have poorer resistance than those already mentioned; hence their use lies in bolts and fixing devices. They may be used also for forged vessels. The mechanical properties of aluminium and its alloys vary with the form of the material; this is shown in Table 2, which

* Summaries of papers given to a recent symposium held by the Institution of Mechanical Engineers on October 28, 1958. Papers read were "Critical Review of Existing Codes of Practice for the Construction of Pressure Vessels in Aluminium and its Alloys", by R. T. ROSE and J. G. YOUNG, "Properties of British Aluminium-base Materials Suitable for the Construction of Pressure Vessels", by E. ELLIOTT, "Fabrication of Aluminium Pressure Vessels", by J. F. LANCASTER and "Experience with Aluminium Pressure Vessels", by C. A. TERRY and G. B. ROBERTS.

Table 1. Compositions of Some Wrought Alloys

Element	N4	N5	N6	N5/6	H14	H30
Cu	0.10	0.10	0.10	0.10	3.5–5.0	0.10
Mg	1.8–2.7	3.0–4.0	4.5–5.5	3.5–5.5	0.4–1.5	0.4–1.2
Si	0.6	0.6	0.6	0.6	0.7	0.6–1.3
Fe	0.7	0.7	0.7	0.7	0.7	0.6
Mn	0.5	1.0	1.0	1.0	0.4–1.2	0.40–1.0
Zn	0.1	0.1	0.1	0.1	0.2	0.1
Ti	0.20	0.20	0.20	0.20	0.3	0.20
Cr	0.5	0.50	0.5	0.5	—	0.5
Al	balance	balance	balance	balance	balance	balance

Table 2. Some Mechanical Properties of Wrought Alloys

Alloy	*Condition*	0.1% *Proof Stress* (*ton/in²*)	*U.T.S.*	*Fatigue Strength* (*ton/in²*)	*Ultimate Shear Stress*
1B.(P)	½H	—	6.5–8.0	—	—
N4(5)	½H	1.2	15.0	8	9
N4(P)	M	—	12.0	—	—
N5(S)	½H	11.0*	—	—	—
N5/6(P)	M	8.0	—	9	11
	O	7.0	—	—	—
N6(S)	O	8.0*	17.0	8.5	—
	½H	14.0	19.0	9.5	—

O = annealed; ½H = ½ hard temper; ½H = ¼ hard temper; M = as manufactured; S = sheet; P = Plate; and * typical only.

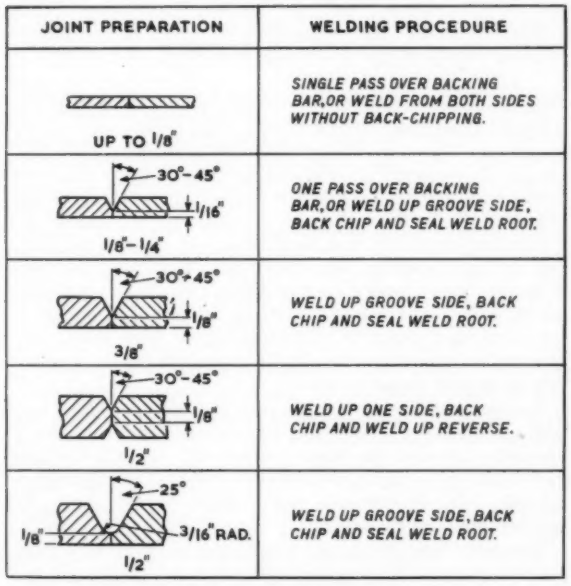


Fig. 2. Typical joint preparations for manual tungsten inert-gas welding.

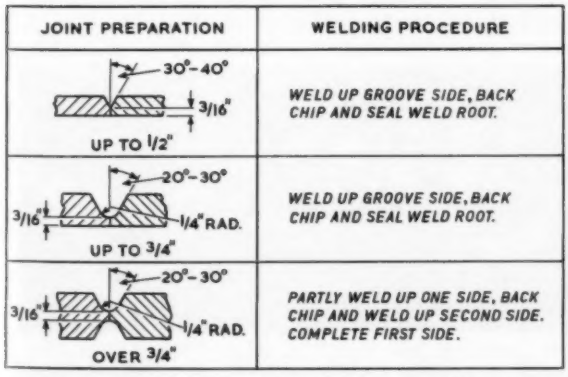


Fig. 3. Typical joint preparations for manual inert-gas metal-arc welding.

is a selection from a number of tables presented by the author.

An important difference between the pure metal and non-heat-treatable alloys on the one hand, and the heat-treatable alloys on the other, was that the ratio, fatigue strength to tensile strength, is 0.5 for the former as against 0.35 for the latter. Data on creep, tensile, and fatigue resistance at elevated temperatures and a number of figures were presented to show the behaviour of the alloys selected for consideration; thus, fatigue strength appears to be reduced at a rate comparable with tensile strength.

The author reports that little has been published on the low-temperature properties of aluminium and its alloys. Tests on pure aluminium, N3, N4, N5, N5/6 and H30 casting alloys show that, without exception, reduction of temperature is accompanied by increase in proof stress and tensile strength, an effect particularly marked in the case of heat-treatable alloys in the fully heat-treated condition. With alloys containing 3½% magnesium and more, there is a slight decrease in ductility, but with aluminium and the more highly alloyed non-heat-treatable alloys ductility increases and none of the materials tested showed brittle behaviour in impact tests. Tests carried out on aluminium magnesium wrought alloys have also shown an absence of tendency to brittle fracture.

Turning to the properties of welded butt joints, the author gave figures for tensile-strength tests. A ½-in. plate in NP5/6 butt welded in the "as delivered state" gave a figure of 17 tsi, and low-temperature tests failed to reveal brittleness.

After outlining the reasons for the corrosion resistance of aluminium and its alloys, the author drew attention to the effects of alloying constituents. Mn, Mg, Si are the least harmful to corrosion resistance, but copper is especially detrimental to corrosion resistance. Contact with noble metals, especially copper, is harmful, although contact with some austenitic steels is not harmful in many media.

Corrosion affects other properties and, in addition, the problems of stress corrosion and corrosion fatigue arise. Most metals form alloys which may fail in certain environments through stress corrosion, and those containing more than about 5% Mg are liable to this type of failure.

Fabrication of Aluminium Pressure Vessels

MR. J. F. LANCASTER (KELLOGG INTERNATIONAL CORPORATION) said that the choice of material is confined at the outset to aluminium and the non-heat-treatable alloys and he rejected the Al-Mg-Si alloys on account of their poor weldability. These alloys are, however, suitable for forged vessels, but there is a risk of stress corrosion with alloys of Mg content greater than 6%, as there is with 5% Mg alloys when used in the range 80° to 175°C.

Cleanliness is essential at all stages of fabrication. In bending and rolling the plates should be coated with paper or plastic material. Prior to welding the surface must be carefully cleaned. Chemical and mechanical means can be used for this purpose, but chlorinated solvents should never be used, since they decompose under the influence of the welding arc.

The choice of the welding method will be determined by the vessel design and workshop requirements. Oxyacetylene and oxyhydrogen processes tend to be used now for light work only. Metallic arc welding is not yet suitable for pressure-vessel fabrication, since the welded joint is inferior to that produced by the inert gas process, which is the natural choice for pressure-vessel fabrication.

The manual, inert-gas, tungsten-arc process gives welds of high quality in plate up to ½-in. thickness. Above this thickness the inert-gas, metal-arc process is the more satisfactory. The tungsten-arc method, however, gives good

control of penetration and is often used for the root runs in thick material. The inert-gas, metal-arc process is preferred to the tungsten inert-gas method for fillet welds. Its upper limit has yet to be determined, but satisfactory welds have been made in plate up to 4½ in. thick. The inert-gas processes are subject to typical defects which affect the choice of one or the other. Inclusions of tungsten, copper and oxide films can arise from the tungsten-arc process. Of the two former, copper particularly impairs corrosion resistance, while oxide films weaken the joint and make it leak-prone. Another common trouble with the tungsten-arc is porosity, but how much of this is tolerable has yet to be ascertained. However, the author reports that when weld reinforcement was left on a welded seam in NP5/6 plate the joint efficiency on removing the reinforcement fell from 93% with no porosity, to 69% with extensive coarse porosity, which also increases the attack on the weld by nitric acid.

Preheating vessels of non-heat-treatable alloys in plate over ½ in. thick in the range 100° to 250°C is often used to improve the weld profile, to remove the cooling caused by a heavy section close to the weld or to reduce porosity in inert-gas, metal-arc welding. The finish of the welded joint is also important. For example, where the reagent is strong nitric acid at high temperature, the welds should be hammered to a flush finish, either at 250° to 350°C or in the cold followed by annealing at 350°C. For other chemical duties, pure aluminium welds may be left in the as-welded condition, while joints in aluminium-magnesium alloy vessels should be ground in order to eliminate the notch effect of the weld bead.

When gas-welding was used danger of flux traps prevented the use of fillet welds, a restriction no longer necessary with the introduction of inert-gas shielded processes. Nozzles are now attached by fillet or butt welds, depending upon the requirements of the vessel. Fittings may be fabricated from plate or from forged blanks. When machining a connection for butt welding to a vessel its length should not be less than four times the metal thickness. Castings are sometimes used for fittings or flanges on light-duty vessels. Threaded joints in pure aluminium and soft alloys are unsatisfactory, but threaded components made in aluminium-5% magnesium or aluminium-magnesium-silicon alloy in the fully heat-treated condition are satisfactory. Otherwise, a threaded austenitic stainless-steel liner may be pressed in the aluminium part and used with a stainless-steel metal component.

These practices, however, came under fire from MR. J. A. WILLIAMS (LAPORTE LTD.). Binding of aluminium threads can be prevented with molybdenum disulphide paste, although if this is used it must not interfere with chemical processes taking place in the equipment. Another treatment is to apply a suspension of P.T.F.E. in polyvinyl alcohol to the threads. The use of stainless-steel male and female parts, as suggested by MR. LANCASTER, also has its difficulties, since the work-hardening of stainless steel leads to greater binding of threads than in the case of aluminium.

Electrolytic action between copper-based alloys or mild steel and aluminium must be prevented by insulation or by cathodic protection; copper components should never be used in aluminium vessels for, apart from electrolytic attack, a few ppm of copper in water leads to pitting attack. Where copper fittings have to be used, they must be insulated from the aluminium by means of plastic washers. Mild-steel support frames also require treatment; bitumen coating or galvanising may be used, or, where there is a large area of contact, sheet zinc is often placed between the two materials. Both methods may be used in combination.

Figs. 2 and 3 give examples of edge preparations. It will be noted that, although similar in form to those used for steel, the angles are greater and the root-radii are more generous. Permanent backing bars are seldom used, but removable bars of this kind in steel or cast-iron are satisfactory, provided the groove is sufficiently deep. Closing-welds in vessels which offer no internal access are best made with a broad U preparation, the first run being made with the inert-gas, tungsten-arc process. Cutting is performed as for steel, although an alternative is to use the inert-gas metal-arc. A recent method uses the tungsten-arc, argon-arc torch using hydrogen as a shielding gas.

In discussion the author corrected the impression that before the advent of argon arc and similar processes aluminium was seldom used for pressure vessels. He acknowledged the 40 years experience of successful gas-welding of aluminium pressure vessels. MR. ROBERTS (I.C.I.) also made a point that gas-welding is widely used for exchangers for working pressures of the order of 300 psi.

Part of MR. J. A. WILLIAMS' very able contribution dealt with copper inclusions in joints welded by the inert-gas metal-arc process, which in his experience were not only very common, but were often very extensive as well, and some, in welded joints, had copper contents as high as 4%. Defects of this kind, which are not revealed by radiography and which require prolonged exposure to nitric acid for detection, must be eliminated before the inert-gas, metal-arc process can be used with absolute confidence.

Process Equipment in Aluminium and its Alloys

SOME EXAMPLES OF chemical plant fabricated from aluminium were described by MR. C. A. TERRY (I.C.I.) and MR. G. B. ROBERTS (MARSTON EXCELSIOR). These included parts of an aluminium sulphate plant (Fig. 5) used for the absorption of carbon dioxide in ammonia. Previously in this process cast-iron had been used, and to reduce corrosion external cooling was employed—a measure fruitless in warm climes owing to the higher, cooling-water temperature. The plant is constructed from NP3 and, as a result, cheaper supports and foundations have been used. The higher operating pressure of 7½ psi has led to a reduction in coding water costs.

For designing these absorbers, which are 5 ft high and 13 ft in diameter, the stress was based upon the tensile strength. The wall thickness varies from ½ in. for the first 11 ft of height to ⅜ in. for the remainder. Circumferential-stiffening ribs of extruded section were welded externally at intervals of 3 to 4 ft.

The eight heat exchangers were made from ¼-in. NP3 plate with cast LN20 header tanks and, since the time the plant was commissioned in 1953, there has been no perceptible attack except for pitting corrosion on the water side of the heat exchangers. This was reduced by adding 2 ppm of sodium chromate to the water.

Fig. 4. Clips intended for fitting trays inside aluminium columns. Pickling revealed defective flash welding of studs.

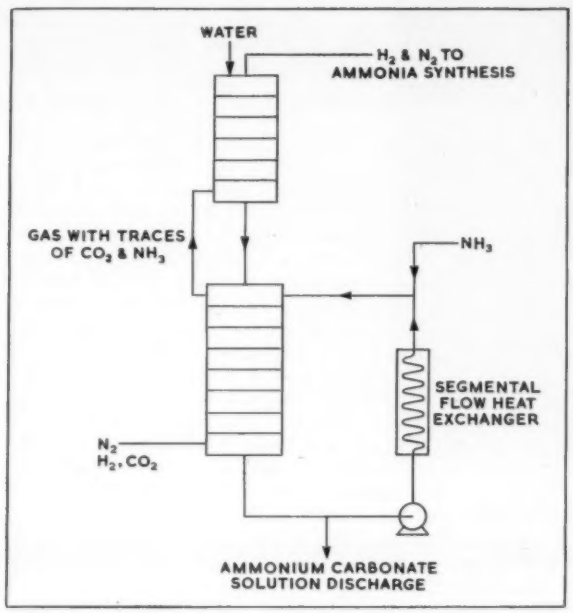


Fig. 5. Ammonium carbonate stage of ammonium sulphate manufacture; plant uses vessels in N3 alloy.

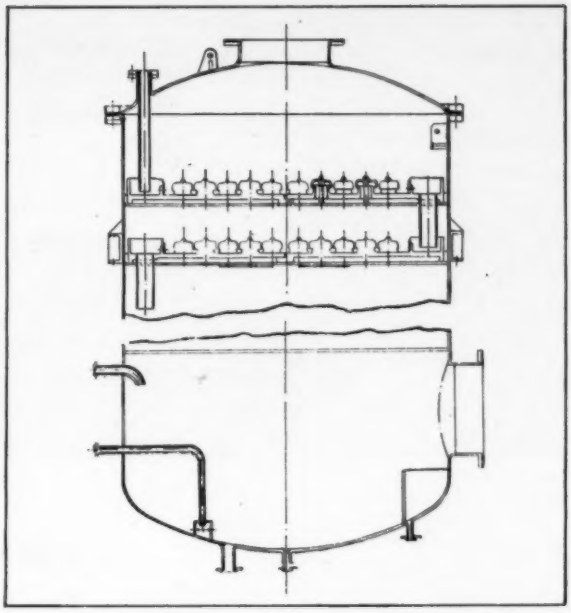


Fig. 6. A nine-deck bubble-plate, tail-gas scrubber for a formaldehyde plant.

Formaldehyde by oxidation of methanol is another process using aluminium plant. Vessels are required for air cleaning, formaldehyde, absorption, and the removal of traces of formaldehyde and methanol from the vent gases. One plant operates at a pressure of 67 psi and uses pure aluminium vessels designed according to the A.S.M.E. code. These gas-welded vessels have the following dimensions: air scrubber, 9 ft × 5½ ft dia.; absorber, 24 ft × 4 ft 10 in.; and tail gas scrubber, 14 ft × 4½ ft dia. (Fig. 6). Plate thickness in each case is ⅜ in., which is greater than the thickness required to withstand the process conditions. It is sufficient for stiffness and allows hydraulic testing in a vertical position. The authors described also an 18 ft × 7 ft dia. absorber constructed from NP3 alloy with the argon arc. This vessel had on its exterior supporting sections, attached by means of intermittent fillet welds, which soon corroded and had to be removed. This experience shows that argon-arc fillet welds are not immune to corrosion from atmospheric influences, despite the absence of corrosive flux residues which occur when gas welding is employed. In the latter case, prevention of entrapped residues from contact with the air by suitable design can give corrosion-free joints.

The absence of ductile brittle transition, common to many ferrous materials, makes aluminium a very suitable material of construction for gas-separation plants, and in this field light alloys are replacing established materials such as copper and stainless steel. The use of alloys like NP5/6 has led to improvements in structural design and reduction in cost. Aluminium also has the advantage not possessed by copper of having a stable market price. A recent tonnage-oxygen plant with two distillation columns employs NP5/6 for both the vessels with pipework in the same alloy fabricated from plate and NP3.

In discussion the authors suggested that when aluminium is used at moderately elevated temperatures, that the two-thirds proof stress criterion could apply even in those instances when it is greater than one-quarter of the uts.

To the examples given by TERRY and ROBERTS, MR. SELIGMAN, of the A.P.V. Co., added a number of others. These included a liquid oxygen container, constructed according to B.S. 1470 in NS6. This vessel (Fig. 1) is 10 ft in length, 3 ft in dia. and 1¼ in. thick, with spherical ends of 1 in. thickness. The working pressure is 800 psi, and its working temperature is 190°C. The vessels were stress-relieved at 350°C for 30 min. and then allowed to cool slowly in air. The weight of each vessel was approximately 1½ tons. Apart from gas-separation plants, there are other low-temperature applications, such as the storage of liquid methane. Two vessels for this purpose under construction for the North Thames Gas Board will each contain 1000 tons of methane. They will be 50 ft in dia. and 100 ft in height and will have a 3-ft layer of powder for insulation. The plate material is to be NP5/6 of thickness varying from ⅜ to ⅝ in. The vessel will contract as much as 2½ in. in length and dia. between the ambient temperature and working temperature of −180°C. Its joints are to be thoroughly examined by radiographic, vacuum, penetration dye and gas techniques.

Vessels for the manufacture of hydrogen peroxide were also described. An 80-ft-high extraction column, 9 ft in dia., w.p. 17 psi at top and 35 psi at base, had plate thickness varying from ⅜ to 1⅛ in. Another vessel 42 ft high, 10½ ft dia., was ⅛ to 1⅛ in. thick; yet another of 12 ft dia. and 61 ft high varies in thickness from ¾ to 1⅝ in.

From MR. J. A. WILLIAMS' fund of experience came another unusual example of corrosion (Fig. 4). This centred around a method of securing fittings, such as distillation trays, inside aluminium pressure vessels. An attempt had been made to use screw clips of HE10 (similar to HS30) to hold the trays in position. They were made by flash welding studs to the alloy strips, the studs previously being zinc sprayed to give a good contact during welding. In order to make the equipment suitable for the chemical process for which it was designed, pickling in caustic soda and nitric acid was necessary, a treatment which was found to produce severe corrosion at the welded joint; so much so that a stud could be quite easily knocked off the clip. This example illustrates the pitfalls in a very useful method for attaching fittings to aluminium vessels; it also shows the value of pickling prior to putting pressure vessels into use.

Fig. 1. An aerial view of the new Misterton factory of The Farmers' Co. Ltd.

£250,000 FERTILISER WORKS

The Farmers' Company's new Misterton Works has a production capacity of 30,000 tons a year

SITUATED ideally on the borders of Lincolnshire, Nottinghamshire and Yorkshire, in the centre of a noted agricultural area, The Farmers' Co. Ltd.'s new fertiliser works at Stockwith Road, Misterton, built at a cost of over £250,000, was officially opened in November last by the Rt. Hon. Lord Quibell in the presence of the directors and shareholders of the company. The new factory is an extension of the company's activities in the manufacture of fertilisers and animal foods and brings their total acreage devoted to these enterprises to over 70 acres. The main products to be manufactured at Misterton are granulated, concentrated, compound fertilisers, with a production capacity of up to 30,000 tons a year.

Although in principle there is no outstanding departure from the conventional processes for the manufacture of granulated fertilisers, the plant at Misterton has had the advantage of the experience gained at the company's other works so far as its layout is concerned. The whole process, from raw material to finished products, is such that it is one of progressive movement. The raw materials are brought in by barges to the riverside berth, where they are unloaded to storage by a travelling overhead crane. From storage the raw materials are fed into a proportioning and weighing plant from which, after weighing, they are conveyed to the granulating plant where they are pulverised, mixed and granulated. The desired end product is finally screened to size and conveyed to storage for ultimate bagging (see Fig. 2).

If any one piece of plant in the process deserves to be called unique it would be the proportioning and weighing system which has been built to the company's own design. This system is the heart of the whole process, enabling, as it does, the concentration of the various raw materials required so that each can be fed in the desired quantity to the granulating plant. The system consists of six raw materials storage hoppers; one being for the recycled process fines, the other five being fed by an overhead grab. Situated at the bottom of the hoppers are rubber conveyor belts which are press-button actuated by a weighman.

In operation, the weighman selects the raw materials from the hoppers as desired by pressing the necessary push-button. At each selection, the raw material is discharged into the hopper of the weighing machine, the accumulative weight being indicated on a dial. When a complete batch is weighed off, the weighman, by pressing a further push-button, operates electric thrusters attached to the gates of the weigh hopper, allowing the batch to proceed forward along an endless belt to the granulating plant. It is of note that only two men are involved in the above operation, which, in itself, is a complex one: the weighman and the operator of the overhead grab. This is typical, however, of the company's Misterton factory, which has been designed to give a maximum of production with a minimum of labour, physically and numerically.

Treatment of Effluents

Effluents at Misterton are treated in two ways. First the hot air and gases from the dryer and the air cooler are treated separately in cyclones for the removal of the dust burden. Two dust-settling chambers follow and these serve chiefly as a safeguard against cyclone failures. The gases are then washed with water, again in separate towers—retention times being of the order of 10 sec. for the cooler gases and 20 sec. for the dryer gases. Sumps at the bases of these towers allow for the collection of sludge formed by small-size dust. The water used is of the order of 10 gal. per 1000 cu. ft gas. The two streams of gases are then mixed in a brick chamber which acts first as a condenser, before water droplets are removed by impingement upon vertical collection slats. The velocity of the gases in the chamber is about 5 ft per sec. The treated gases for dispersal then pass to a chimney 120 ft high.

In the treatment of liquid effluents the wash water, which cuts across the air system described above, and the condensate are filtered and neutralised in a duplicate bed of graded limestone. At this stage the used wash water of *p*H 3.0 is neutralised to a value of *p*H 6.5, and is passed into storage in a duplicated storage system for further

use. When the dissolved solids content of the water becomes too high for effective washing, it is used as granulating process-water whenever possible or, failing that, pumped to waste after cooling to, or below, the the maximum permissible temperature.

New Fertiliser Process

Some details of experimental work initiated by Mr. R. B. Risk, the company's managing director, were also given (see Fig. 3). This is a new process for the production of concentrated compound fertilisers, which will give increased plant food value for the same amount in weight of similar type products produced by present known processes. As such, compound fertilisers containing calcium superphosphate were first granulated in measurable quantities in the early 1940s. The processes developed depended on the physical properties of the superphosphate for the binding of the granules. Superphosphate, sulphate of ammonia and muriate of potash were the usual fertilisers to be mixed and granulated by controlled wetting and manipulation. Cold water was generally used in the wetting stages of the processes, although both hot water and steam were used in work done in the late 1930s, and the advantages of the preheating of the powder mixture observed. With the above substances and using cold water in the granulator, operating conditions existed which permitted visual granulation control of the mixture before feeding to the dryer, the controlled heating having no appreciable effect on the chemical or physical natures of the ingredients. When ammonium nitrate was substituted in part for ammonium sulphate (1943), visual control at the granulator became impossible when using cold water. This was because of the greatly increased solubility of ammonium nitrate in hot water, and was countered by "underwatering" in the moderate temperature of the granulator. When using ammonium nitrate, or other salts with similar solubility characteristics, visual control of granulation was restored by raising the temperature of the mixture in the granulator by the use of steam or heated gases.

In cold granulating, water is required first for wetting (dependent on surface area, surface tension and the temperature of the crystals), and, secondly, in excess of this for efficient granulation with the superphosphate in the existing conditions. For granulation in a rotary conditioner this quantity is approximately one-seventh of the water which would be required to completely dissolve the weight of crystals in question at a temperature of 100°C.

By the new process (F.C.L. Compound Fertiliser Process, B.P. No. 791004), however, the company say that it is now possible to manufacture granulated, concentrated, mixed fertilisers containing plant food ratios of over 2.5:1 nitrogen (N) to phosphorus (P) and 2.5:1 potassium (K) to phosphorus (P). On this basis, fertilisers containing up to 50 plant food units have been produced. This is a hot granulation process, so control is visual. A feature of the new method is that dihydrate process phosphoric acid can be advantageously used as produced at the acid-plant filters. The sulphuric acid normally present in technical phosphoric acid is at times sufficient for the needs of the granulation process. The phosphoric acid is produced at the company's Barton-on-Humber works.

A 10-ton-per-hour fertiliser granulating plant of orthodox design is now in the course of being extended at the company's Barton-on-Humber works to work according to the new process. The detailed design of this plant and a unit for the continuous ammoniation of phosphoric acid has been entrusted to the Sturtevant Engineering Co. Ltd., London, working in co-operation with The Farmers' Co. Ltd.'s own technical staff.

The Barton-on-Humber works, at which the manufacture of fertilisers has been carried on without a break since 1873, has been the site of many original developments, as in 1942 the company installed a granulating plant and were among the first to produce granulated fertilisers. In 1953, a phosphoric acid plant was installed to enable the company to manufacture triple superphosphate for use in concentrated compound fertilisers and here, also, the first fertilisers in Great Britain containing the insecticide Aldrin were produced and offered commercially.

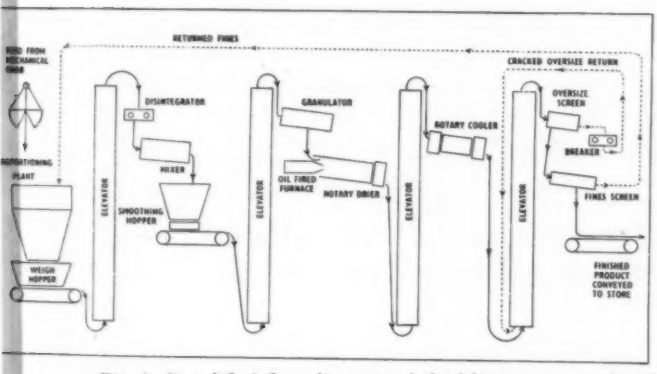


Fig. 2. Simplified flow diagram of the Misterton granulated fertiliser process.

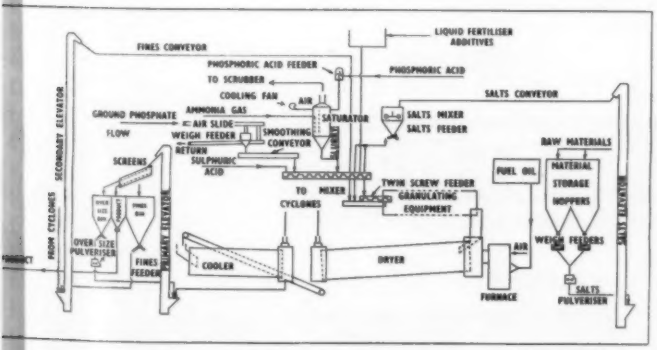


Fig. 3. Flow diagram of the experimental process for the production of granulated, concentrated, mixed fertilisers.

Room for Development

The manufacture of fertilisers is but one facet of the company's activities, and at Misterton there is room for developing the site (7½ acres) to include an animal feedingstuffs and a crop-spraying depot. At present the factory area covers 6 acres, has a river frontage of ¼ mile, and the rate of intake of raw materials is 50 tons an hour. The raw materials storage capacity is 4000 tons, the finished product storage is 7000 tons, and the capacity of the bagging plant is 25 tons an hour. Approximately 40 men will be required to maintain the stated production capacity.

The buildings and plant were designed and their erection supervised by the company's own staff. Contractors and suppliers to the company include: Allen, West & Co. Ltd. (motor starters and control gear); W. & A. E. Brealey (Machinery) Ltd. (disintegrator); Brush Electrical Co. Ltd. (switchgear); Codd & Drewry (gas cleansing chambers and chimney); Fishers Ltd. (bagging plant); G.W.B. Furnaces Ltd. (steam-raising equipment); Hepburn Conveyor Co. Ltd. (proportioning plant, elevators, conveyors, etc.); Lancashire Dynamo & Crypto Ltd. (electric motors); Manlove, Alliott, Co. Ltd. (rotary dryer and cooler); Schieldrop & Co. Ltd. (oil-fired furnace); and Sturtevant Engineering Co. Ltd. (cyclones and fans).

SURFACE TENSIONS OF COMMON LIQUIDS

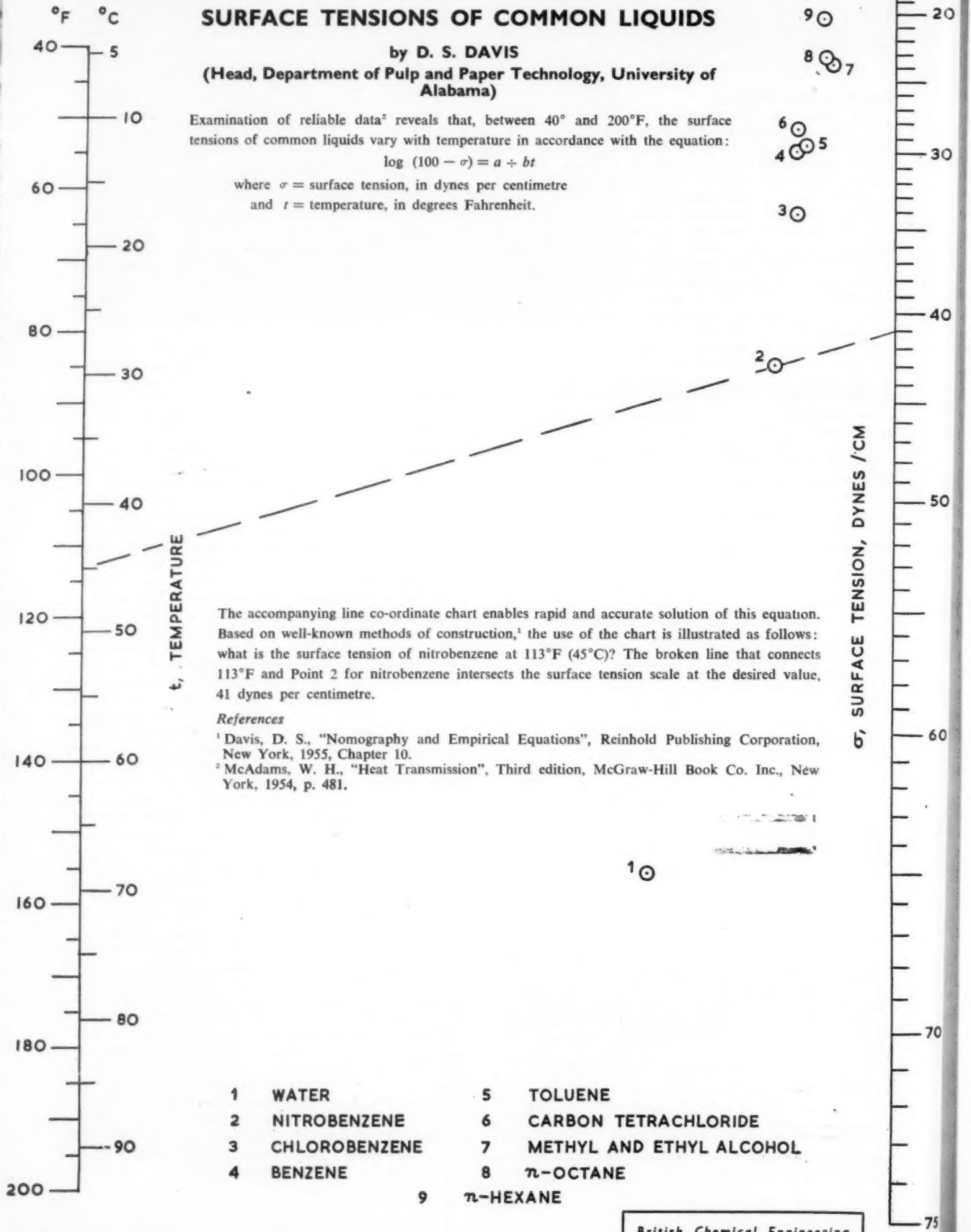
by D. S. DAVIS

(Head, Department of Pulp and Paper Technology, University of Alabama)

Examination of reliable data[2] reveals that, between 40° and 200°F, the surface tensions of common liquids vary with temperature in accordance with the equation:

$$\log\ (100 - \sigma) = a \div bt$$

where σ = surface tension, in dynes per centimetre
and t = temperature, in degrees Fahrenheit.



The accompanying line co-ordinate chart enables rapid and accurate solution of this equation. Based on well-known methods of construction,[1] the use of the chart is illustrated as follows: what is the surface tension of nitrobenzene at 113°F (45°C)? The broken line that connects 113°F and Point 2 for nitrobenzene intersects the surface tension scale at the desired value, 41 dynes per centimetre.

References

[1] Davis, D. S., "Nomography and Empirical Equations", Reinhold Publishing Corporation, New York, 1955, Chapter 10.
[2] McAdams, W. H., "Heat Transmission", Third edition, McGraw-Hill Book Co. Inc., New York, 1954, p. 481.

1	WATER	5	TOLUENE
2	NITROBENZENE	6	CARBON TETRACHLORIDE
3	CHLOROBENZENE	7	METHYL AND ETHYL ALCOHOL
4	BENZENE	8	n-OCTANE
		9	n-HEXANE

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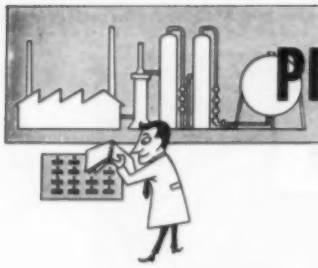
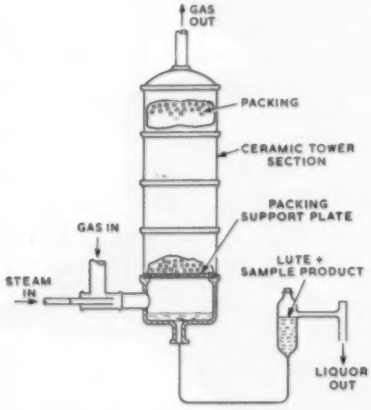


PROCESS ENGINEER'S NOTEBOOK

A Small-scale Absorption Tower for SeO_2

THE EXIT GAS from the SeO_2 condenser is passed to an absorption tower in which the small amount of SeO_2 in the gas is removed by absorption in water as selenious acid. Because selenium and its compounds are toxic, the whole of the plant is operated under a mild vacuum, and this, together with the corrosive nature of the selenious acid produced, makes the operation of the normal tower difficult.

In addition, it was essential to obtain the maximum concentration of selenious acid for recovery of selenium by SO_2 stripping.



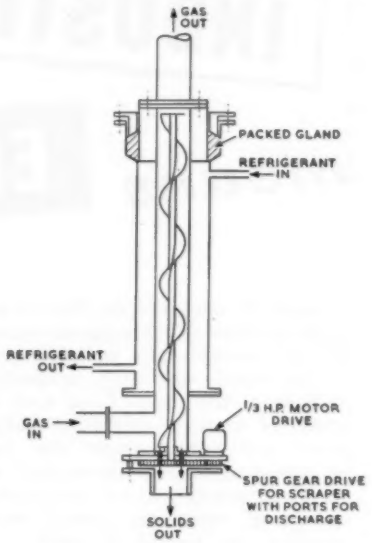
The absorber outlined on the accompanying sketch was developed to overcome these difficulties. The steam injected into the gas inlet pipe to the tower maintained a slight vacuum through the plant, which was enhanced by the condensation of the steam in the tower and packing. The tower operated as a combined co-current tower with steam and gas, and as a counter-current tower with condensate and gas. Since the dioxide is extremely soluble in water, it was found that this gave an effective and efficient tower capable of producing a strong solution of acid.

J. MOLYNEUX

A Small-scale Sublimation Condenser for SeO_2

PURE SELENIUM DIOXIDE is made on a semi-technical scale by passing pure gaseous oxygen from a liquid-oxygen source over metallic selenium carried on silica trays and heated in an electric furnace. The resulting gaseous selenium dioxide is collected in a scraper condenser as colourless crystals. The temperature of the condenser is maintained at a low level by circulating brine in the cooling jacket and thereby ensuring the maximum recovery of oxide.

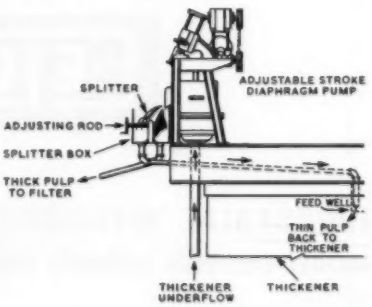
The general construction of a condenser found to be satisfactory on a small plant is illustrated in the accompanying sketch. The body consisted of a length of standard-bore, stainless-steel tube fitted with a M.S. jacket. The spiral and ports were also fabricated in stainless steel, but to reduce the risk of contamination the spiral was tipped with resin-bonded glass-fibre. Since there is a toxic hazard involved in handling this dioxide, manual operations are reduced to a minimum and the crystal is fed from the ports into a sealed container. The spiral, in addition to scraping crystal from the walls and conveying it downwards to the discharge ports, considerably increases the heat transfer and maintains it at a constant value.



Splitter Box for Return of Thin Pulp to Thickener

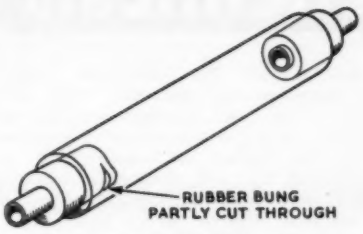
WHEN THE SOLIDS are being discharged from a thickener, this simple device, developed by the Denver Co., makes it possible to separate the thin suspension from the thickened material. The splitter makes use of the fact that, through its lower viscosity, the thin pulp has a much higher velocity when it is discharged by the diaphragm pump. This causes the stream of suspension to pass over the edge of the splitter plate and to return to the thickener for further treatment. The more dense suspension, on the other hand, having a greater viscosity, is not discharged with a velocity as great as the less dense material, and as a result the stream does not clear the edge of the splitter. Instead, it is diverted to the filtration plant.

The position of the splitter plate is adjusted by means of a handle attached to a threaded shaft whose end is free to revolve in a retaining collar fitted to the movable plate. Rotation of the wheel alters the position of the plate. This is a useful feature, since it enables the splitter to cope with changes in concentration of solids in the feed to the thickener, without serious loss of pumping capacity throughout the cycle.



Simple Non-return Valve

A SIMPLE NON-RETURN VALVE for handling corrosive liquids in the laboratory or the small pilot plant is readily made from a glass cylinder and two rubber bungs or stoppers. At the smaller end of the inlet bung a piece is almost sliced off, a small segment only being left to keep the slice attached to the bung. The larger end is drilled and the valve assembled as shown in the accompanying diagram. Operation is quite simple; pressure of the liquid forces the flap open and allows the liquid to pass. If the flow is stopped the flap closes and prevents back-flow. A little experimenting with the depth of cut may be necessary, since too shallow a cut may cause too great a resistance to the flow of the fluid.



SIMPLE CHECK VALVE

Vessel with Twin Jacket

WITH SOME PREPARATIONS it is necessary to heat up the reactants and then, once the reaction is under way, to apply cooling to remove the heat of reaction. One way of doing this is to have the heating and cooling connections to the jacket or cooling coil of the reactor. This arrangement always means a multiplicity of valves which can sometimes lead to confusion. It also has the disadvantage, depending upon the mass of the heated or cooled material, that a certain amount of time-lag occurs between the time the heating or cooling is applied, and the time either becomes effective. A more flexible arrangement is to have a twin-jacket system built in with the vessel, one for the heating medium, which may be steam, dowtherm, etc., and the other for the cooling liquid, which may be water, brine and so on. This dual arrangement will give much better control at the point where it is desired, i.e., at the changeover from heating to cooling.

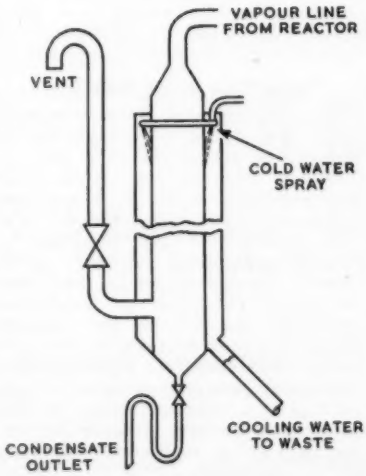
Scrubber for Acid Fumes

THE STEAM-JET EJECTOR with direct barometric condenser was used to evacuate a small tank used for holding a charge of acid for a neutralisation process. At first the possibility of the nuisance arising from the discharge of acid vapour from the condenser outlet was overlooked. The problem was solved by injecting a solution of caustic soda into the condenser water. This was effected by fitting between the water inlet to the condenser and the valve controlling the water supply a small Edwards-type jet pump. With N caustic soda a required ratio of pumped to pumping liquid of around 1 : 10 was obtained by a pinch-valve on the pump suction connected to a drum of caustic soda solution fitted with sight glass and manual stirrer.

Spray-cooled Condenser

IN THE PREPARATION of sodium methoxide at the Boots corticosterones plant, Beeston, Nottingham (see also *British Chemical Engineering*, 1958, **12**, 689), it is necessary to remove methanol entrained in the hydrogen-containing vapours from the reactor. To avoid the contents of the reactor (sodium and anhydrous methanol) being contaminated with water through leakage from the condenser, a water-spray-cooled model of the design shown (right) has been constructed. It is mounted high on the outside of the thick walls of the isolated sodium methoxide preparation building.

(Courtesy of Boots Ltd., Beeston, Notts.)



Tower Packing Support Plate

THE IMPORTANCE of support plate design for packed columns is well recognised and many types are available, such as straightforward flat grid-supports and conical grids of greater free area than provided by the flat type. Apart from strength, rigidity and reasonable cost, a support plate must be so designed that it avoids high pressure losses and consequent flooding at a point below that characteristic of the packings.

A satisfactory support is readily fabricated from welding type pipeline reducers and m.s. plate; the reducers are tack welded to holes cut either on square or equilateral triangular pitch in the circular piece of plate. The larger ends of the reducers are uppermost. The number and size are fixed by the gas throughput; for a 1-ft column 1½-in. reducers are a convenient choice. The plate is drilled with a number of holes of ¼ in. diameter to allow the liquid to pass out of the section and of a number to give a slight submersion of the perforations themselves. If another packed section is present below this one, then the holes should be drilled on a circle, concentric with the vessel, of about ½ the vessel's diameter. Wire mesh is placed over the upper ends of the pipe fittings to retain the packings. This type of support will give a good separation of liquid and gas phases, will not involve high pressure losses, and will satisfactorily redistribute the liquid over the packings below.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Indian Fermentation Industry

Mr. Manubhai Shah, the Indian Minister of Industry, inaugurating the Development Council for Alcohol and Fermentation Industries, at a ceremony in Delhi recently, asked the council to prepare a ten-year programme for the utilisation of industrial alcohol for chemical and plastic products. The Minister said that the first plant for the manufacture of polythene in India, using alcohol as a raw material, would be commissioned early in 1959. This would consume about 2 million gall. of alcohol a year. Another polythene plant with a similar capacity was expected to go into production early in 1960.

Plants for the manufacture of acetic acid and butane had been licensed. All these industries would utilise about 10 million gal. of alcohol per year. A synthetic rubber plant, which would be set up in the private sector at Bareilly, would have a capacity of 20,000 to 30,000 tons of rubber per year and would consume about 12 million gal. of alcohol annually. It would be in full production early in the third five-year plan period.

The target for the production of alcohol had now been fixed at 45 million gal. per year by the end of the second Plan. This would make India one of the largest industrial and power alcohol producing countries in the world, the Minister said.

Paper Production

The Swedish State Forestry Industries Co. (Statens Skogsindustrier A.B.) has decided to build a pulp and a paper mill adjacent to the wallboard mill at Pitea and a new mill, of a type unspecified as yet, at Kalix.

At Nanterre, France, the Cellulose de la Seine, a subsidiary company of the Papeteries de la Seine, is now manufacturing paper pulp from non-resinous wood in a pilot plant using a process developed by the Lyons Municipal Laboratory. After removal of the bark, the wood is reduced to shavings which are impregnated with a sodium monosulphite liquor, under pressure, at the lowest possible temperature and for the shortest possible time. At 135°-145°C digestion takes 2-3 hours; at 150-155°C it takes 30-45 minutes.

Monsanto is to build a plant at its Seattle, Wash., installation for the manufacture of Mersize, a fortified resin size used in paper manufacture.

Cement Plant for Ghana

An agreement for the construction of a cement clinker plant at Takoradi, Ghana, has been signed in London by Mr. Botsio, Ghana Minister of Trade and Industries, and by Mr. N. M. Jensen, chairman of the Tunnel Portland Cement Co. The plant, it is estimated, will cost £600,00, of which Tunnel and the associated companies in the venture will provide 75% and the Ghana Government the remainder. There will be a *pro rata* representation on the board of the new company. Equipment is being supplied and installed by F. L. Smith & Co. Ltd., consulting engineers to Tunnel. A new wharf is to be built at Takoradi, costing about £400,000, at which ships will discharge the clinker. The plant is expected to produce between 100,000 tons and 125,000 tons of cement a year, or between one-half and one-third of Ghana's annual requirements.

Belgium's Plastics Imports

Belgian imports of plastics materials have been rising rapidly and in 1957 totalled 26,320 tons valued at the equivalent of £6.9 million. Imports from the United Kingdom totalled 4,168 tons in 1957 and were valued at £1,056,487. They showed an increase of 25% by value on the previous year's figures and accounted for 3½% of the U.K. total exports of plastics materials. Despite keen competition from the U.S.A., Germany and the Netherlands, the U.K. is supplying about 15% of Belgium's total imports of plastics materials.

New Celanese Plant

The vinyl acetate plant of C.S.R. Chemicals Pty. Ltd., Rhodes, New South Wales, built with technical assistance from British Celanese Ltd., and commissioned in August, 1958, in advance of the contract date, is operating at a higher rate of output and efficiency than was specified in the contract. It is the third vinyl acetate plant which has been based on research done at Spondon by British Celanese, the other two being the Spondon plant itself and that built by the Celanese Corp. of America.

A further expansion in the plant for the production of Courlene X3, a polythene yarn developed by Courtaulds, is taking place at the Little Heath, Coventry, factory of British Celanese Ltd. By early 1959, output is expected to be doubled. New advances in plant design and production techniques are being incorporated in the installation.

Solar Pans in the Dead Sea

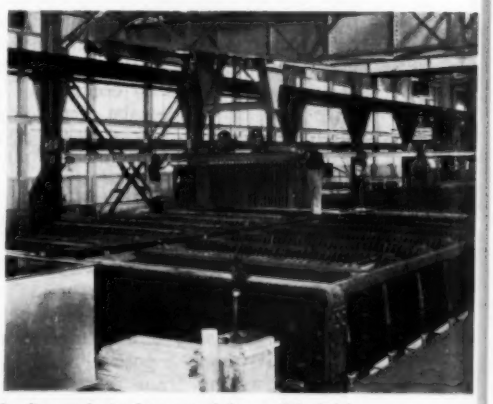
One thousand men are now working on the Arab Potash Co.'s project for the recovery of potash and other mineral substances from the brine of the Dead Sea, supervised by L. H. Manderstam & Partners, London. The immediate task is to rehabilitate the area designated for carnallite solar pans and the construction of a pilot plant for the production of potash. The pans and installation, previously operated by the Palestine Potash Co., were destroyed by the Arab armed forces during the Palestinian war. The installation and operation of the pilot plant is intended mainly for collecting data on new processes to form the basis for a commercial-scale plant in the near future.

Rubber-Chemicals Agreement

Naugatuck Chemical division, United States Rubber Co., and Farbenfabriken Bayer A.G., Germany have agreed to exchange know-how and patents on chemicals used in the manufacture of rubber products.

Non-ferrous Metals Production

The first stage of an important new development being undertaken by the Rhodesian Selection Trust Group of companies was completed by the opening recently of the third electrolytical copper refinery at Ndola, Northern Rhodesia. The refinery now has a capacity of 55,000 tons per year and extension is still going ahead for completion, it is expected, in 1960. The process includes the electrolysis of a copper sulphate solution producing a pure cathode copper (the anode is copper as received from the smelters) and, secondly, the treating of the copper in a wirebar furnace. In the electrolysis a continuous circulation of the copper sulphate solution in all deposition tanks is maintained at the rate of four gallons a minute. The temperature is kept at 140°F.

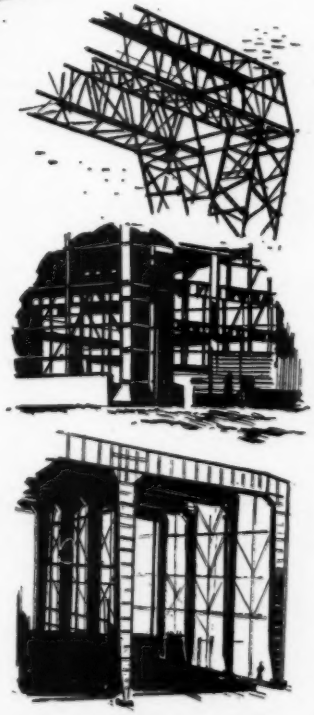


Loading anodes in the new tank house of the Ndola, Northern Rhodesia, electrolytic copper refinery.

The growth of non-ferrous metallurgy in the U.S.S.R. in 1958 was second only to that of the oil industry, according to a recent statistical survey. Production in the first nine months of the year was 11% higher than in the corresponding period in 1957. In the past three years exports of copper, zinc, lead, tin and aluminium have increased from 142,000 tons in 1955 to 207,000 tons in 1956 and 291,400 tons in 1957. During the course of the year some of the newly discovered deposits of non-ferrous metals have been brought into production. In East Kazakhstan the first trainloads of polymetallic ores were extracted from deposits claimed to be exceptionally rich in lead, zinc, copper and rare metal contents.

Deutsche Edelstahlwerke, an August Thyssen Hütte subsidiary, and Titanium Metals Corp., of America have founded a company to promote the consumption of titanium products in Europe. The new company, Continental Titanium Metals Corp., has its headquarters at Luxembourg.

taking the stress



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Book Reviews

Chemical Process Economics

by J. Happel

Chapman & Hall, London, 1958, 291 pp., 68s.

THIS is a remarkable book. The subject is intensely specialised, and it is said that the specialist is the man who knows more and more about less and less. But this is no description of the author of "Chemical Process Economics". To follow him is to read the *Encyclopædia Britannica* on a switchback or, with LAIKA in the Sputnik, to get a rapid glimpse of a thousand fabulous lands. It is a fascinating miscellany of almost mediæval charm—every page with a titbit for the man who wants to understand the sorcery of profit making in the atomic age. Basic economics, linear programming, theorems about partial differential equations, statistics, the design of heat exchangers and a final chapter on the social values of an engineering economy give the book a character both live and unexpected. One sees now why the profession of the chemical engineer was so long in achieving recognition, at least in Britain; the subject, to judge by this book, is a kaleidoscope of learning, holding many mirrors up to many lights. But it remains true learning for all that. Each chapter goes to its fundamentals, or else gives references to finding them. When the author introduces rules of thumb, as he must in so comprehensive a work, he is careful to designate them as such—even to sweep them together, away from the analytical results. In my view this is a book that could be read with profit by many students of management, both old and young, and they need not be chemical engineers. Anybody who has either to design or to run an industrial plant that is supposed to pay for itself before it finally shuts down will get six new ideas and half a dozen illuminations of old ones within an hour of first opening its pages.

The series of vignettes of which the work consists opens with a couple on basic economics; the differences between marginal profits and profits that will attract capital; the concept of "venturework" that sweeps into one figure all the various parameters that can be employed to suggest how attractive a venture can be. All this is fundamental and intensive. The third chapter is about the logical structure of management decisions shown as illustrations of mathematical analysis, concepts of optimisation, of functional relationships, of boundary conditions, of stochastic processes and of sophisticated techniques like linear programming. Chapter four is full of empirical tips about estimating costs, and chapter five on the mathematics of risk and recovery of investment. This chapter in particular should be read by anybody who has got so far as to dip his big toe into the waters of speculation. Chapters six and seven deal in a very condensed way with what might be called the internal balance of a plant; they are highly specialised, written for the chemical engineer who has to carry real responsibility and who might like to know where he can find a sympathetic hand-hold. Finally, the book is unusual in the way it ends—with four substantial appendices upon the derivations of some of the formulæ, upon practical tips, upon current costs of common materials and other working rules.

R. W. REVANS

Current Trends in Heterocyclic Chemistry

Butterworths Scientific Publications, 1958, 170 pp., 30s.

THIS little book contains the proceedings of a symposium held in Canberra in September, 1957, and consists of 20 papers and a verbatim report on the discussions which followed them. There is also an index of subject-matter. Among the subjects dealt with are the following: reactions of ethyl diazoacetate with heterocyclic systems; the reaction of benzoyl peroxide with heterocyclic compounds; factors influencing electrophilic substitution in nitrogen heterocycles; physico-chemical studies on solubilised porphyrins; the effect of heteroelements in modifying some cyclisations; the linear naphthiminazoles; a novel type of naturally-occurring quaternary base; hernandine—a new aporphine alkaloid from *Hernandia bivalvis* Benth.; some alkaloids of Australian *Crotalaria* species; syntheses of pyrimidine nucleosides; and hydropteridines and their biological role.

As will be seen from the above list, the papers cover a wide field in synthetic, physico-chemical and biological chemistry although most of the work described has already been published. Some of the papers are of a high standard and some points of interest emerge from the discussions. There are some erroneous formulæ (on page 2) and the text suffers from looseness of expression only admissible in spoken language. Since material difficulties may have prevented them from attending this symposium in far-off Australia, chemists in this country interested in the heterocyclic field will welcome the publication of its Proceedings.

M.P.

Finite Queuing Tables

by L. G. Peck and R. N. Hazelwood

John Wiley & Sons Inc., New York, Chapman & Hall Ltd., London, 1958, 210 pp., 68s.

OPERATIONS research, or the application of probability theory to predicting the most efficient way of conducting a campaign, was used with great success in military operations in the last war.* Since then the same probability techniques have been used in sales forecasting, the planning of traffic highways and airports and other engineering and general industrial applications. One aspect of operations research, the theory of queuing, has been used for determining the number of runways required at a civil airport, the channels required for an efficient telephone service and similar problems where a number of "customers" and a smaller number of service points are involved. This approach is most useful when determining the number of machines required for a certain process or the amount of preventive maintenance required for optimum plant efficiency. It may also be applicable to the problem of residence or holding times in reactors.

The "Finite Queuing Tables" by Peck and Hazelwood, of the Arthur D. Little Operations Research and Mathematics Group, Cambridge, Mass., is the second of the volumes sponsored by the Operations Research Society of America. They provide solutions to problems where the population (number of customers, number of machines, etc.) may range from 4 to 250. The tables list in parallel columns: the service factor (a ratio of the average service time divided by the average service time plus the average idle time), the service channels (repair men, number of telephone lines, number of valves and so on), the delay probability (the probability that if a unit calls for service it will have to wait), and an efficiency factor (a quotient made up of the average number serviced, the average number idle and the average number awaiting service).

The tables were computed on Univac I and printed straight from the magnetic tape. The plates were subsequently produced by the photo-offset process, so that no errors in typesetting could occur.

The brief introduction gives several examples of queuing problems, and those wishing to use the tables on similar problems should have no difficulty in doing so without further reference.

W. STRAUSS

* Morse, P. M., and Kimball, G. E., "Methods of Operations Research", Technology Press and John Wiley & Sons, New York, 1950.

Recent Advances in Petroleum Chemistry and Refining—Volume I

Edited by Kenneth A. Kobe and John J. McKetta, Jr.

Interscience Publishers, London, 1958, 641 pp., 103s.

VOLUME I of this new series of annual progress reports on advances in petroleum chemistry and refining consists of five groups, of which the first deals with economics and future trends, the second, unit operations and design, the third, refining processes, the fourth, petro-chemicals and the final group with mechanical equipment. These volumes are intended primarily to enable the man engaged in one branch of the petroleum industry to learn what is going on in other fields, but in view of the wide range of processes and products in the petroleum and petro-chemical industry, they should be of interest to all chemical engineers.

The plan in the individual reports in each group is to give an introductory discussion of the background information or theoretical processes considered, followed by a section dealing with large-scale operation and plant and a short summary. Although this is the general pattern, it is not strictly followed, and

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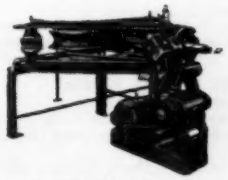

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Book Reviews (continued)

some reports are concerned largely with manufacture, whereas in others a thorough discussion is given of the more theoretical side with little information about industrial practice. The treatment throughout is a little uneven, as is almost unavoidable in a book of this character in which 21 authors are concerned, but usually two authors jointly write the individual report.

In the economics group, the first article by R. J. GONZALEZ on petroleum operations in the United States gives a lucid and fascinating account of what might have been a relatively uninteresting subject, including a forecast of the future supply position. The next report deals with the production of petroleum and the final report with fuel trends and again attempts a forecast of the future, in particular as regards both quantity and quality of liquid fuels. The authors of this last report, BEATTY and LOVELL, also discuss the likely changes in the motor gasoline quality and the effect of the development of new types of engines such as free piston engines.

The unit operations and design group commences with one of the longest chapters in the book on separation and purification by crystallisation; methods and plants for the separation of waxes, xylenes and urea adducts are discussed and a case is presented for the advantages of crystallisation over distillation and extraction processes. The next chapter on fractionation is primarily concerned with the theoretical background, but the following chapter is concerned with new fractionating-tray designs in considerable detail, particularly as regards operating characteristics.

Of refining processes, alkylation, catalytic reforming and solvent refining are considered, but only the section on solvent refining deals to any appreciable extent with the chemical engineering aspects of the design of the plant. It is pointed out that ignorance of the chemical composition of lubricating oil and of the mechanism of solvent extraction may have contributed to the lack of development of new lubricating oil and solvent extraction processes.

F. H. GARNER

Automatic Control—Principles and Practice
by Werner G. Holzbeck
Rheinhold Publishing Corp. New York,
Chapman & Hall, London, 1958, 258 pp., 60s.

Automatic Process Control
by Donald P. Eckman
John Wiley & Sons, New York,
Chapman & Hall, London, 1958, 368 pp., 72s.

THE first of these books could well have been entitled "Automatic Process Control for Chemical Engineers". Both the context and style are to be commended. The book is essentially non-mathematical and succeeds in presenting both the principles and application of automatic control in a manner that permits their clear understanding by students as well as process engineers, since there is no need to draw on a mathematical knowledge beyond H. N. C. standard. The text is well written, non-ambiguous and convincing. The remarkably few errors noted are typographical and do not detract from the quality of the work.

Some chapters in the book may not be interesting to chemical engineers, but the others amply justify its recommendation. Basic concepts are first discussed using the conventional forms of resistance and capacitance in a process stage. A short chapter on static characteristics says much in a few pages. There are excellent chapters on step function and frequency responses of systems and adjustment of controllers that alone make this volume a useful acquisition. Plant engineers will welcome the practical qualitative methods described for determining controller choice and settings based on the classic papers of ZIEGLER and NICHOLS and a more recent article by OPPELT. The chapter on frequency response includes a delightfully clear section on stability conditions in a control circuit.

Chapters on mechanical and electrical components, balances and computing circuits are of lesser interest from a process viewpoint, but the chapter on measuring elements is informative and valuable, giving useful data on time-constants of different types of temperature-measuring elements under various conditions. The chapter on final control elements includes an analysis of valve characteristics and the two closing chapters on control systems and industrial applications will appeal particularly.

Even after taking consideration of the reviewer's bias towards an author who defines volume capacitance of a gas as standard cubic feet per psi of pressure change as against ft² (*vide* accompanying review), chemical engineers can confidently accept his recommendation that this is a book well worth acquiring.

THE second-named work is disappointing. DR. ECKMAN, the author, has been teaching instrument engineering at the Case Institute of Technology since 1950, having previously served seven years as research engineer for a well-known instrument company, and it would have been hoped that this work would be a useful contribution to control literature. It fails largely because the author calls a spade a manually manipulated means for terrestrial excavation, with the result that even the simplest points appear complex. The material in the book has been culled from a wide range of sources and includes much that is good, but, obscured by the author's presentation, the quality becomes lost. In content, it covers a similar field to the previous work reviewed, but is mathematical with the language of elementary operational calculus, treating from an early stage in terms of transfer functions. The chapter on process characteristics makes an unfortunate start in stating "In chemical engineering a unit process involves a change of chemical state", having in the previous sentences defined a process as an operation. GIBB's phase rule would have been more happily omitted from this chapter, and flow rate could have been introduced as a third important characteristic of fluid and thermal processes. Gas capacitance is given as ft² deriving from failure to differentiate between pounds mass and pounds force (p. 22) and R, the gas constant, is given strange units. In discussing NEWTON's second law of motion, f = force, lb, and M = mass particle, lb-sec²/ft. These examples serve to indicate the gap between the mode of thought of the author and the chemical engineer to whom lbm and not lbf is the fundamental. Further potential sources of irritation are the unfamiliar usage of symbols throughout the book and such units as $Btu/ft^2\ sec^{-1}\ deg^{-1}$.

The book contains a praiseworthily large number of illustrations, questions (with an appendix of answers) and worked examples. It is presumed that these are largely free of error, although one of the few examples checked by the reviewer proved incorrect (p. 53 Ans = 36 sec), and the variable ratio speed reducer described on p. 64 (fig. 3-4) could only act as a constant or zero speed device, apart from indeterminate slip.

The general conclusion is that, with a fair knowledge of process control, the text can be understood, sometimes with effort, but the worth-while matter in the book is to be found more clearly expressed in other texts. Written in more direct style with some rearrangement and the omission of much extraneous and unnecessary matter, it could have been a useful work.

N. J. HASSETT

British Standards

Rationalised and Unrationalised Formulæ in Electrical Engineering. B.S. 2290:1958 4s. 6d. The MKS rationalised system of units is being more and more widely used by electrical engineers. In these tables the forms of the more important relations in electrical science are given in the rationalised and unrationalised systems. They supplement B.S. 1637.

General Recommendations for the Sampling of Manganese Ore. B.S. 3035: 1958. 4s.

Shorter Notices

Packaging. Productivity Review 30. British Productivity Council, London, 1958, 80 pp., 5s. A review of productivity in packaging is presented in this booklet which discusses variety reduction, machinery, special containers, metal containers, plastics and allied subjects.

Big Molecules, by Sir Harry Melville, F.R.S. G. Bell & Sons Ltd., London, 1958, 180 pp., 15s. This book is based on a series of Royal Institution Christmas lectures; the author describes both natural and man-made big molecules. The lectures were delivered to "a juvenile auditory", but may also be interesting to adults.

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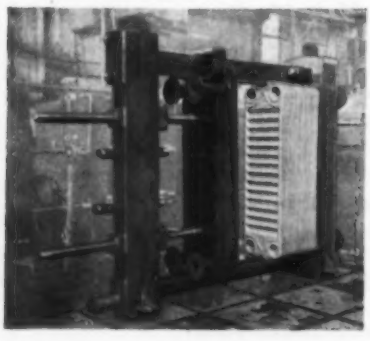
can flow. By cutting the supporting edges at certain places, continuous channels may be formed in any way which is suitable for a particular job. Heat-transfer figures are in the neighbourhood of 2000 Btu per sq. ft °F hr. Grooving the back of the tiles can increase the heat-exchange area at the back by 40% with a corresponding increase in heat transfer on the inside, and under favourable conditions transfer values of about 4000 Btu per sq. ft °F hr have been achieved. The topmost course of tiles is machined so that it lies flat against the tank and seals the topmost channel. If there is pressure, e.g., from steam heating, a stuffing box of gland design is employed for the top course. **Cahn & Bendit Ltd., 51 Weymouth Street, London, W.1.**

BCE 4513 for further information

Titanium Plate Heat Exchangers

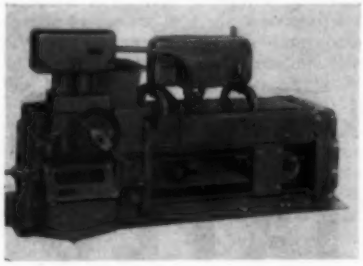
As a result of co-operation between the A.P.V. Co. Ltd. and the Metals Division of Imperial Chemical Industries Ltd., three Paraflow heat exchangers with heat-transfer plates of pure titanium have been supplied to one of I.C.I.'s Divisions. The picture shows one of these units during testing procedures in A.P.V.'s shops. The choice of the plate type of exchanger was influenced by the fact that the area of the heat-transferring surface is kept to minimum in those machines, and that the use of expensive materials of construction is limited to the transferring surfaces only. All other parts of the equipment in contact with the corrosive liquid are protected by a cheaper material, which in the machines supplied to I.C.I., is ebonite. Although the application for which the three models are intended is not disclosed, A.P.V. suggest that a field in which titanium-plate heat exchangers may be of value include cooling processes utilising sea or estuarine waters where copper-based alloys cannot be used for certain reasons. They point out, in particular, the food industry. **A.P.V. Co. Ltd., Crawley, Susex.**

BCE 4514 for further information



Scale and Dry Feeders

The totally-enclosed construction of the Merchen scale feeder now available from Wallace & Tiernan makes the machine suitable for dangerous or easily-contaminated commodities. An accuracy is claimed for it of rather better than ±1%. Material entering the feed section from above falls on to a supported weigh-belt, is carried under a flow-controlling gate and then over a section where the weigh-belt is counterbalanced by a pre-set weight on a scale-beam. The



action of the gate is dependent on impulses from the weighing mechanism to increase or decrease the flow. The feeder may be fitted with remote rate-of-feed control and arranged to meter chemicals in proportion to liquid flows or to suit any other continuous process. Their dry chemical feeder, type PA-690, has been designed to deliver measured amounts of chemicals with a positive, self-cleaning action. Combined with hopper agitation, which is optional in the same unit, the action of the feeding mechanism, it is stated, eliminates arching, clogging or flooding of materials. Two alternative methods for solution mixing are incorporated in the unit—using a swirl-type, twin-jet agitated chamber of corrosion-resistant plastic or a 25-gal. tank with triple jet. A mechanical mixer can be fitted if required. **Wallace & Tiernan Ltd., Power Road, London, W.4.**

BCE 4515 for further information

Multiple Graphite Heat Exchanger

Robert Jenkins have added a further model to their range of Polybloc graphite heat exchangers which they manufacture under licence of Société Le Carbone-Lorraine. The new model, the Super, is available as a standard with a heat exchange area of 528 sq. ft in a single unit. It can be built up from individual units having a minimum area of 37.7 sq. ft in multiples of 37.7 sq. ft. **Robert Jenkins & Co. Ltd., Ivanhoe Works, Rotherham, Yorks.**

BCE 4516 for further information

Pipes from Steel Strip

Welded steel pipes manufactured from steel plate or strip by the Driam patented process are being marketed by B.S.P. The strip is formed into a con-

tinuous helix and the adjoining longitudinal edges are then butt-welded together. B.S.P. point out that automatic submerged arc welding is used with two passes, one inside the pipe and the other outside, to ensure full penetration of the weld through the thickness of the plate. Their tests have shown that the pipes' mechanical and physical properties are at least equal to those of similar pipes manufactured from the same quality of steel by any other process. The tensile tests of the helical joint indicate that failure always occurs in the parent metal and not through the weld. The process of making the pipes, it is said, ensures that they are straight and round to an exceptional degree of accuracy. They are being made in the range of 10-28 in. and can be supplied in any length, subject only to the limits of transport, and in two standard grades of steel. **British Steel Piling Co. Ltd., 10 Haymarket, London, S.W.1.**

BCE 4517 for further information

Pneumatic Slide

W. S. Barron are now producing a pneumatically-operated slide which can be adjusted to open fully and intermediately and also to act by inching or

BCE 4447 for further information

We delved into Kaolin clay....

. . . and came up with this faster way to dewater it.

Kaolin clay processing is largely a matter of slurrying, settling in tanks and dewatering in large quantities.

One of the first jobs is to separate the clay into particle size ranges for various purposes and Sharples centrifuges are already widely used in this classification operation. The finest of these grades is the clay for coating fine quality printing papers. It is in the final processing of this fine fraction clay slip that we at Sharples were asked to help.

First the fine fraction slip can be flocculated by sulphurous acid, then settled by gravity to a concentration of 20% clay solids. Then comes the difficult and expensive process of dewatering by filter press to 65% solids ; especially expensive since the filter press has to be constructed of stainless steel to withstand the corrosive nature of the slurry.

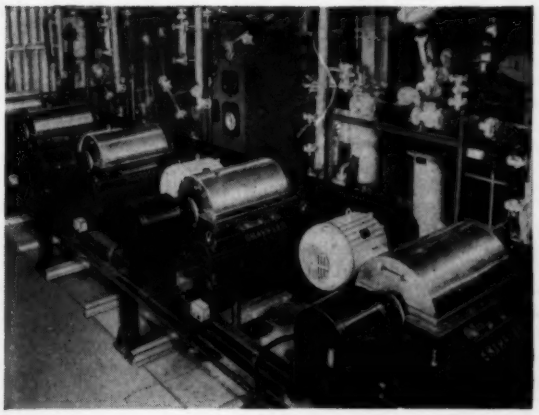
Doubling the capacity of the filters

After experimenting with various Sharples centrifuges, we found a method whereby Sharples Nozljectors would dewater the clay slurries from 20% to 40-50% solids continuously and at high throughput capacities. In this way, the clay producer could at least double the capacity of his filters by pre-thickening the clay slip fed to a filter. The Nozljector-filter press combination could then handle a given clay throughput at a substantially reduced capital investment, and with great economy in ground space requirements.

Unique Engineering Service

Kaolin clay is only one example of the Sharples Centrifugal Engineering Service in action. Whatever your separation problem may be, Sharples experts are always ready to investigate and advise. Sharples is the only concern in Britain able to offer a complete range of centrifugal machines for any separation purpose, so you can be sure of unbiased advice.

Write to us and we'll be glad to send you Report No. 2956M showing the Sharples range of continuous centrifuges. Or, if you wish, 'phone Camberley 2601 and talk to Martin Trowbridge about your problem.



An Installation of Sharples Super-D-Canters, one of the wide range of Sharples Centrifuges.

SHARPLES

Sharples manufacture a complete range of Continuous Centrifuges, including—

THE SUPER-CENTRIFUGE SERIES • THE DD-2 DISC BOWL SERIES • THE DH-2 NOZLJECTOR SERIES • THE DG-2 AUTOJECTOR SERIES • THE DV-2 VALVE NOZZLE CENTRIFUGE SERIES • THE SUPER-D-HYDRATOR CRYSTAL CENTRIFUGE SERIES THE Q-18 SELF-DISCHARGING CRYSTAL DEWATERER SERIES • THE SUPER-D-CANTER SLUDGE DISCHARGE CENTRIFUGE SERIES THE 1A LABORATORY CENTRIFUGE SERIES • THE SUPER CLASSIFIER SERIES • THE SHARPLES MICROMEROGRAPH

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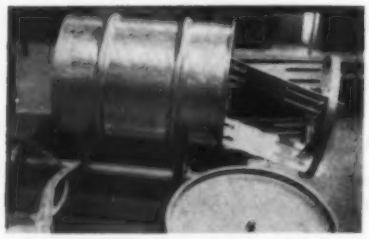
PLANT EQUIPMENT NEWS

by reciprocating as a feeder to a weigher. The slide is adaptable to remote control, and runner bars are provided to avoid build-up of material. The slides are made in six standard sizes from 6 to 14 in. sq., but the design can be modified to suit existing conditions. **W. S. Barron & Son Ltd., Gloucester.**

BCE 4518 for further information

Drum Mixer



In the Manesty drum mixer equipment the mixing drum and fixing paddle are revolved on rubber-tyred rollers. These are supported by a frame which carries the drive unit. Drums and paddles can be supplied in stainless steel if necessary. The drive is provided by ¼-hp motor. **Manesty Machines Ltd., Evans Road, Speke, Liverpool, 24.**

BCE 4519 for further information

Improved Glass Condenser

Improved manufacturing techniques, Q.V.F. say, have enabled them to price their new and improved condenser-type heat exchanger at about two-thirds of the figure at which its predecessor sold. Advantages claimed for the new model include greater compactness and up to a 30% higher heat-transfer efficiency, achieved partly by the use of thinner-walled tubing. Characteristics of the new exchanger, type HEN 4/5, include the following: a heat-transfer area of 5 sq. ft, a free cross-sectional area of 4.68 sq. in., pipe equivalent to free cross-sectional area 2 in., maximum recommended water working pressure across coils 30 psi. **Q.V.F. Ltd., Duke Street, Fenton, Stoke-on-Trent, Staffs.**

BCE 4520 for further information

Fabric Envelope "Tanks"

Portolite tanks—envelopes made from strong coated woven fabrics—have been introduced by Marston Excelsior to provide simple, lightweight containers for the transport and storage of a range of liquids. The tanks are available in a black or white finish. When holding bulk liquids they can be easily conveyed by normal road, rail or water transport, the makers say, and on the return journey the empty tank can be rolled up into a small bundle, allowing the full load space of the returning vehicle to be used for other cargo. The tanks may be strapped on to the flat deck of an open-sided vehicle or placed within the walls of a vehicle with sides; the walls should, however, be strong enough to withstand the loads imposed by the contents of the tank. Surge can be reduced to a minimum by ensuring that little or no air is allowed to enter the tank during filling. A tank is most stable when completely full, and a partly filled tank should be suitably lashed, it is pointed out. The flexibility of the tanks enables them to be used for on-site storage on unmade ground.

For cleaning, steam and detergents may be used, and the fitting of a second connection may help to dispose effectively of steam and condensate. The fabric of construction is governed by the proposed contents which may include petrol, mineral and vegetable oils, water, latex, chemical salt solutions, alcohols, detergents, molasses, alkaline solutions, ketones, esters, dilute acids and fruit juices. The theoretical maximum working pressure of the standard 1000-gal. model is about 12 psi. **Imperial Chemical Industries Ltd., I.C. House, Milbank, London, S.W.1.**

BCE 4521 for further information

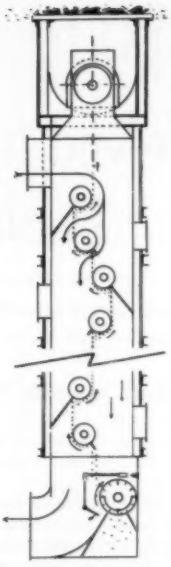
Liquid-cooling Plant

Temperature Ltd. have added to their range of liquid-cooling plants a series of small machines, in power up to 3 hp. They incorporate an hermetically-sealed refrigeration system, and are designed to cool liquids to temperatures between 15° and 75°F. The plastics-bodied pump will handle a variety of liquids at external heads up to 30 ft, and it is rated at 150 gals. per hour. Models are available for temperate or tropical climates and either an air-cooled or water-cooled condenser may be fitted. A single unit has a cooling capacity of about 20,000 Btu per hour. **Temperature Ltd., Burlington Road, London, S.W.6.**

BCE 4522 for further information

Roller Coal Dryer

Neldco Processes, who are to market, under licence, the Conreur vertical roller coal dryer in the United Kingdom, have completed an agreement with W. C. Holmes & Co. Ltd. for its manufacture and installation. The machine, which has been manufactured in France by Conreur Ledent & Cie for the past ten years operates by counter-current drying and consists of a steel tower, divided into sections lined with refractory brickwork. Each section is fitted with two cast-iron rollers, mounted in heat-resisting bearings and driven at low speed from outside by a continuous sprocket chain. A 25-ton-per-hour dryer requires only a 5-hp drive. The interior of the tower is fitted with cast-iron baffles designed to direct hot gasses through the dryer with a minimum of resistance. The hot gases,



produced by any type of fuel, enter at the base and rise through the descending coal. The final moisture content can be maintained within close limits, it is pointed out, and no recirculation of dried products is necessary. **Holmes & Co. Ltd., Turnbridge, Huddersfield.**

BCE 4523 for further information

Vapourproof Light Fitting

A.E.I. have introduced a new 150/200-watt industrial vapourproof tungsten wellglass fitting. It has a corrosion-resistant LM-6-M aluminium alloy canopy, tapped for top entry (1-in. electrical thread), and a heat-resisting wellglass protected by a galvanised wire guard. A 14-in. diameter PVC reflector

is available as an optional extra and the fitting can also be supplied with either a 45-degree angle entry or conventional side entry. **A.E.I. Lamp & Lighting Co. Ltd., Melton Road, Leicester.**

BCE 4524 for further information

Industrial Space Heater

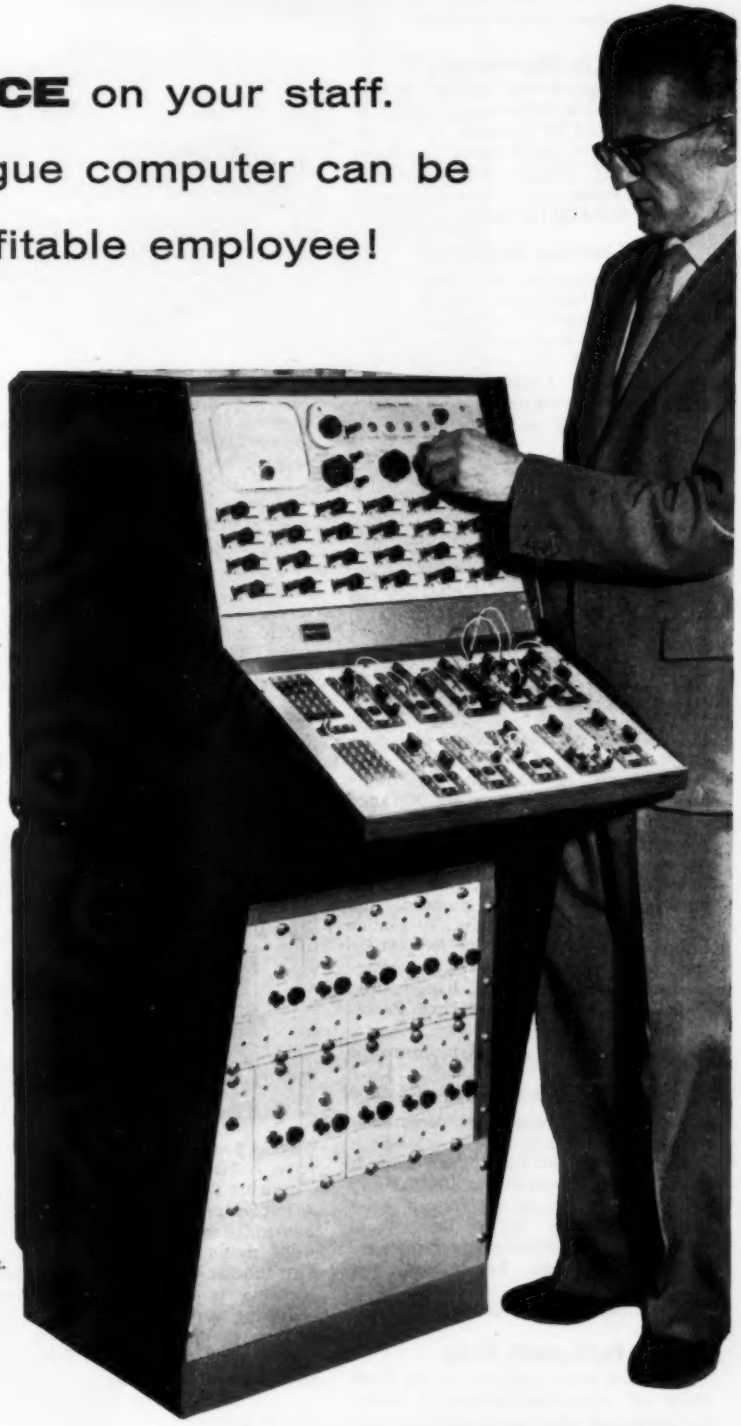
Gulf Radiators have developed and are now marketing a 5-kW oil-filled electric safety radiator for the space heating of industrial premises. It utilises the permanently-sealed oil-filled principle. **Gulf Radiators Ltd., 229 Regent Street, London, W.1.**

BCE 4525 for further information

BCE 4448 for further information

Put **MINISPACE** on your staff.

A Solartron analogue computer can be your most profitable employee!



You, in common with every industry today, are facing more and more complex dynamic analysis problems—from simple differential equations to the simulation of industrial processes.

How much are these problems costing this year—in development and engineering time, not forgetting overheads, and the fabrication of expensive "trial and error" models? And how much has production been delayed?

The analogue computer is the supreme engineering design tool for dynamic problems—proved over many years by the aircraft industry. Its cost is rapidly repaid by savings in development and engineering time—it is much cheaper to simulate your mistakes than to make them.

Contrary to general belief, a practical machine need not be expensive or difficult to use—the Solartron "MINISPACE" costs £1,600, and does not require an electronic or specially qualified engineer to operate it.

MINISPACE is just one example of the SPACE* 'building-brick' principle of construction, which allows a computer of any size to be constructed. Another application for more complex problems is SPACE '48', with up to 48 operational amplifiers. There is infinite scope for expansion or tailoring to your specific requirements.

Solartron advisory engineers will be happy to discuss your problems. Write or phone now for literature.

* SPACE: Solartron Precision Analogue Computing Equipment.

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PLANT EQUIPMENT NEWS

Fittings in High-Impact PVC

A new range of pipe fittings moulded in Geon RA.170, high-impact PVC, has been introduced by Extrudex. The parts include elbow bands, T-pieces, couplings, adapters and flanges. **Extrudex Ltd., Bracknell, Berks.**

BCE 4526 for further information

Oil-burning Equipment

Stordy Engineering are now able to supply, under licence, the complete range of proportioning oil burners and ancillary equipment developed by the Hauck organisation of America. **Stordy Engineering Ltd., Cumbriahouse, Goldthorn Hill, Wolverhampton.**

BCE 4527 for further information

PUMPS

Pump Range Extended

The latest development of Kingsbourne Products is their mark X range of Neumo pumps designed to provide deliveries of up to 1500 gal. per hour. At this rate materials such as sugar syrup, glue, dilute acids and solvents have been successfully pumped, the makers point out. It is basically similar to the mark IV range, but its plunger consists of a piston fitted with a spring-loaded Fluon piston ring. **Kingsbourne Products Ltd., South Coast Road, Peacehaven, Sussex.**

BCE 4528 for further information

Portable Air Compressor

A portable rotary screw air-compressor mounted on a four-wheeled chassis is being manufactured by Holman Bros. It provides outputs of 135 to 600 cfm and delivers at temperatures, Holman point out, considerably lower than those obtained from reciprocating compressors. **Holman Bros. Ltd., Camborne, Cornwall.**

BCE 4529 for further information

Rigid-plastic Pump

The most recent addition to the Gush range of centrifugal pumps is manufactured with the casing and impeller in rigid PVC. A mechanical seal with carbon and stainless-steel components is fitted as standard, but alternative types of seal can be applied; for example, the Crane Fluoseal. The 1-in. pump shown is capable of discharging 5 gpm of fluids similar in viscosity to water at normal ambient temperatures, against a total

maximum head of 43 ft, 20 gpm with a 37-ft head, and a maximum of 30 gpm against a head of 25 ft. **Appleton & Howard Ltd., Salisbury Street, St. Helens, Lancs.**

BCE 4530 for further information

Flame-proof Pump Units

Waynes have introduced the model 300 series of pumps for handling hazardous non-lubricating fluids. Developed from the company's standard model incorporated in their petrol pumps, the rotary internal gear is of circular tooth design which provides a large sealing surface, high volumetric efficiency and great strength and rigidity,

Waynes point out. An adjustable by-pass valve is built in as standard. The unit is suitable for handling all low-viscosity petroleum products and a wide range of industrial solvents. Pump and flame-proof motor are mounted on a light, rigid tubular framework, and models are available in three standard capacities delivering respectively 10, 15 and 20 gpm against a discharge head of 20 psi. **Wayne Tank & Pump Co Ltd., Western Road, Bracknell, Berks.**

BCE 4531 for further information

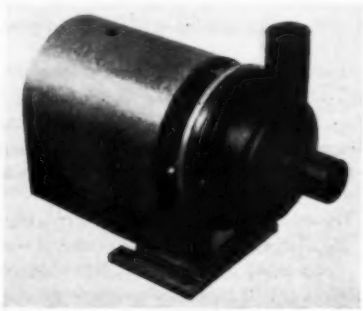
Sump Pump

Flygt pumps are now made available in Britain by the British representatives of the Swedish manufacturers, Midland Tunnelling. The submersible pump is fitted with a single passage impeller and two mechanical seals built together in a single seal pack. On the outside the pump is coated with a black elastic asphalt-rubber varnish to protect against impacts and corrosion. **Midland Tunnelling Co. Ltd., 20 Bentinck Road, Hyson Green, Nottingham.**

BCE 4532 for further information

Small Resistant Pump

The Minnow centrifugal pump by Appleton & Howard measures $7\frac{1}{4} \times 3\frac{1}{4} \times 5\frac{1}{4}$ in. and weighs $5\frac{1}{4}$ lb. Its body and impeller are of high-density polythene and the shaft sleeve is of stainless steel so that the unit is resistant to a wide range of fluids. As standard, a synthetic rubber-lip type of shaft seal is supplied, but a mechanical seal with stainless-steel and carbon components may be fitted if required. For fluids of similar viscosity to water at normal ambient temperatures its capacity is 5 gpm against a head of 2 ft, or 1 gpm against a maximum head

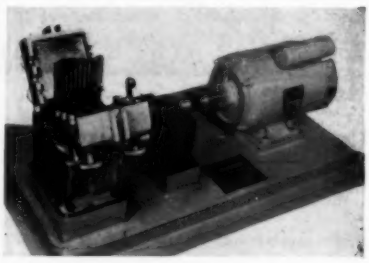


of 11 ft. The pump components and the motor are held in a die-cast aluminium frame with support feet. It can therefore be mounted on bench, or panel, or incorporated in a packaged unit. The suction and discharge branches are suitable for $\frac{1}{4}$-in. bore rubber or plastic hose. **Appleton & Howard Ltd., St. Helens, Lancs.**

BCE 4533 for further information

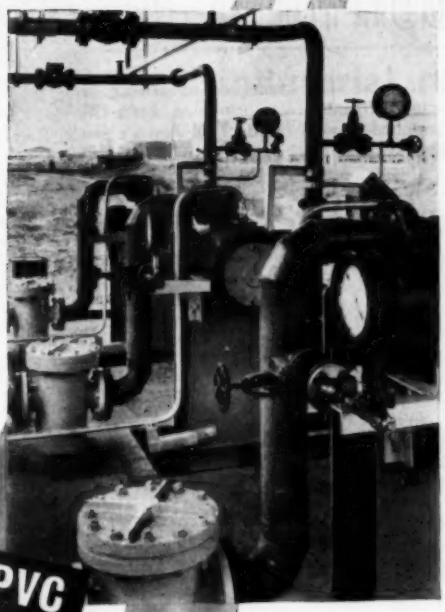
Chemical Pump

The Apex 192 Sinus chemical pump, which is designed to handle liquids or gases, operates by the compression of a rubber tube that carries the fluid between a pressure plate and a number of fingers which work in a sinus movement. The pressure imparts a positive undirectional movement of the liquid, and the design and finish of the fingers, it is claimed, enable the tubing to stand long usage without appreciable wear. The rate of flow may be varied by altering the size of the tubing and by adjusting the speed of the operating fingers or the load placed on the pressure plate. Four sizes of pump are available,



GEON RA 170

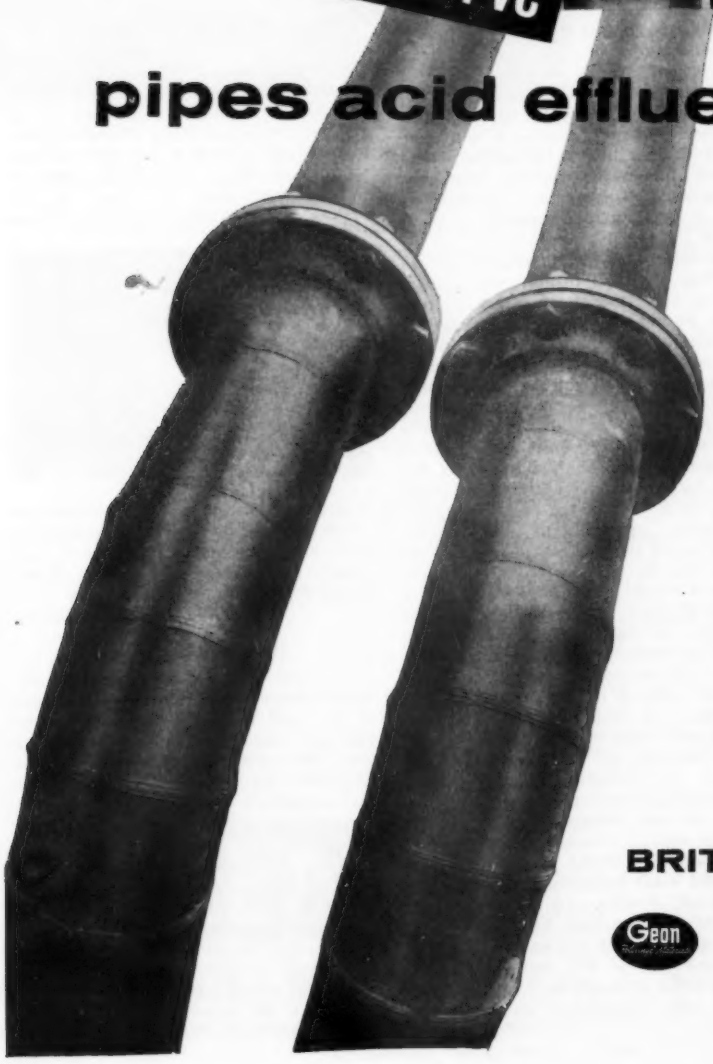
the High Impact PVC



High Impact PVC tubing made by Extrudex Ltd, Bracknell, using Geon RA170. Photographs taken at The British Petroleum Co. Ltd Refinery, Isle of Grain.

Geon is a registered trade mark.

pipes acid effluent safely



Day and night, night and day, 11,000 feet of shatter-proof piping made with Geon RA170 High Impact PVC carries acid effluent safely away from the BP oil refinery on the Isle of Grain.
Geon RA170 was chosen because it combines outstanding toughness—15-times that of ordinary PVC—with high tensile strength, lightness and resistance to chemicals and solvents.
No other PVC so completely satisfies the requirements of piping for the petroleum industry, the chemical industry and all branches of civil engineering.
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giving rates of flow from 12 cc/min. (0.16 gals./hr) to 9000 cc/min. (120 gals./hr). The pumps can be supplied motor driven complete on a baseplate with an infinitely-variable speed reducer. **Apex Construction Ltd., 15 Soho Square, London, W.1.**

BCE 4534 for further information

INSTRUMENTS

Smoke Density Measurers

Londex are offering two instruments to assist in smoke control. They are their smoke alarm, type SAU (made to B.S.S. 2740), providing warning by means of indicator lamps and single-pole changeover output contacts; and their smoke density equipment, type SD, which indicates on a meter the degree of density. A recorder can be connected to the equipment if desired. **Londex Ltd., 207 Anerley Road, London, S.E.20.**

BCE 4535 for further information

Temperature Transmitter

The latest version of the Sunvic pneumatic temperature transmitter, model 33H, uses helium as filling gas in the thermal system. That gas was chosen because of its inertness and good thermal conductivity and because its use enables the thermal system to be tested with a mass spectrometer. The instrument is a true constant-volume thermometer, Sunvic point out. Its systems are of copper or stainless steel, and bulbs for them are available in a variety of forms and sizes, those in copper withstanding 1000 psi static pressure and those in stainless steel up to 1500 psi. Temperature spans of from 50°F (30°C) to 900°F (500°C) can be covered. No standard ranges are offered, each instrument being made to the customer's requirement. Very low temperatures can be measured with it and a sensitivity of the order of 0.01% of the instrument's range is claimed. **Sunvic Controls Ltd., 10 Essex Street, London, W.C.2.**

BCE 4536 for further information

Electronic Tank Gauge

Firth Cleveland state that their new and advanced model of the Gilbarco electronic gauge operates on the patented Gilbarco principle, but it is less expensive than their earlier model. The new gauge is designed for installation on pressure and atmospheric tanks at temperatures up to 425°F and in quarry or underground cavern storage to depths of up to 1000 ft.

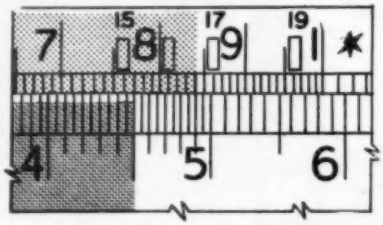
The gauge is contained in one small explosion-proof housing instead of two large ones, weighs 120 lb., and is installed with a 2½-in. standpipe instead of the 4-in. pipe formerly required. Field wiring is also simplified.

The following advantages are also claimed: it reads level in feet, inches and sixteenths regardless of the specific gravity of the liquid; it is power-actuated to overcome the effect of varying friction in pulley sheaves and the variation in the weight of the measuring element at high and low liquid levels; and it can be adapted to almost any type of remote transmission. **Firth Cleveland Instruments Ltd., 7 St. James's Street, London, S.W.1.**

BCE 4537 for further information

Simple Data-processing Systems

Simple printed-paper logarithmic strips are used in the latest data-processing and recording system devised by Gray Horton. The novelty of the system is that as the logarithmic strips are inexpensive a large number of them can readily be used to handle a large number of variables. In addition, adhesive signals may



be employed to affix strips to form stores of information or "visual memories". The system, which demands only an elementary knowledge of logarithms, has two general uses. It may be applied to calculation when it can work with considerable versatility like a computer—for example, an assembly of five strips with appropriate visual memory signals, 6 in. wide, is being used constantly to select one of 222 possible answers.

The system's other general use is for recording—by wall display—the percentage of achievement of target in processes. For this purpose a single pair of logarithmic strips is used for each factor. They may be held in position by a plastic pocket and are slid along each other like the parts of a conventional slide rule. Percentages are shown on the top scale in red and the units are shown in the bottom scale in black. To set the scales for a particular example the target figure (5820 tons in the case illustrated) is placed opposite to the starred 100 mark on the percentage scale. If the target has to be achieved in, say, 20 weeks, the red scale can be marked with signals at every 5% point (equivalent to 1 week). As the figures for production come in from the plant these are indicated by moving a transparent green "cursor" strip along the units strip. The percentage of achievement can be seen on the pink figures immediately against the percentage of the time that has elapsed. The progress of the process therefore may be carefully watched. Another coloured transparent strip can be used to indicate present time.

The situation shown in the diagram is that the total production to date, the 16th week, is 4500 tons, 77% of target. But 84% of the time has elapsed and production is about a week and a half in time and 7% or 400 tons in quantity behind what it should be to achieve target on time, assuming it progresses uniformly.

The device is marketed under the name Intercontinental Computer Strips. **Gray Horton Products, 22 Bruton Street, London, W.1.**

BCE 4538 for further information

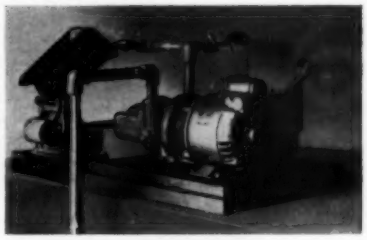
Optical Immersion Pyrometer

The Fosters are now marketing the Foster-Platt optical immersion pyrometer for measuring the temperature of hot liquids such as molten metals in crucibles and ladles. In its design the optical axis of a disappearing filament type of optical pyrometer is extended in a light-tight tube sealed at its outer end with a refractory sheath. On immersing in a bath of molten metal the inner end assumes in a few seconds the temperature of the bath, and as the image of the pyrometer filament is permanently superimposed, a reading is obtained quickly and accurately regardless of the type of alloy being tested, the makers state. In most non-ferrous metals the refractory sheath will withstand up to 150 immersions and 50 in cast iron. **Foster Instrument Co. Ltd., Letchworth, Herts.**

BCE 4539 for further information

Effluent Sampler

A pump type of sampling apparatus for effluent has been introduced to the Lea range of instruments. The pump works at predetermined intervals to fill a tipping vessel of fixed volume, operating, on each occasion, for two or three minutes discharging the liquid into the tippling mechanism to clean out the system. The half-pint sample is retained



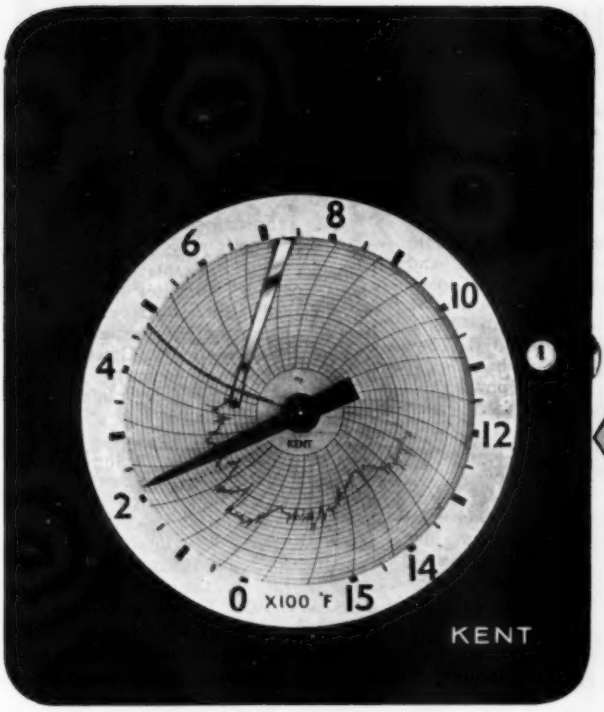
as the flow stops and the mechanism is pivoted so that it will automatically pour the sample collected into a container. **Lea Recorder Co. Ltd., Cornbrook Park Road, Manchester, 15.**

BCE 4540 for further information

Pressure Controller

The new Mason Neilan No. 2807 air-operated pressure controller is designed to be used normally mounted on the yoke of the control valve, but it can also be employed remotely, surface mounted. Similar in many respects to the company's no. 2707 model, it is, however, fitted with a pilot relay of the non-bleed slack diaphragm type having a large air capacity that enables a greater valve stroking speed to be achieved. The valve is interchangeable with that of the 12,800 series level controller. The proportional mechanism incorporates a bellows-operated negative feed-back system, and the proportional band can be adjusted to 1% of the instrument's range. The pressure element

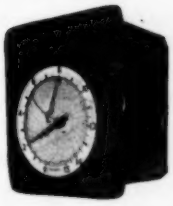
BCE 4450 for further information



industrial command expands with . . .

the new electronic KE

This entirely new high-speed electronic recorder is the latest addition to the KENT *Commander* range of industrial instrumentation, which has already set a new standard in flexibility and ease of maintenance. The KE is intrinsically a circular-chart instrument (ring-scale indication, etc. optional) for such process variables as oxygen percentage; glass level; millivoltage; temperature—in association with thermocouple, resistance thermometer or radiation pyrometer; and temperature difference.



What the K E does

Records
Indicates
Controls
Transmits
Receives

What the K E is

. . . an electronic instrument in the now-familiar *Commander* style of presentation (with attendant advantages of interchangeable-unit construction, etc.), employing fast and continuous balancing by high-sensitivity electronic amplifier and servo motor. Here are some of the KE's features :

- ★ Two speeds of operation—2 seconds or 15 seconds approximately for full-scale travel
- ★ All-mains operation—no batteries
- ★ Entire assembly planned for maximum accessibility; plug-and-socket connections for electronic units
- ★ Choice of amplifiers provides for a wide range of input conditions; amplifier uses standard thermionic valves
- ★ Built-in-upscale/downscale drive for external-circuit failure
- ★ Common ancillary units throughout *Commander* instrument range offer very important advantages to users dealing with a host of measurements (rationalized servicing, maintenance and spares stocks, for example)
- ★ Controlling, transmitting and other units in the new *Mark 30* Series enable even greater stability, etc.

To find out more about the Commander KE, write for Publication 352 and 993, or telephone . . . Chemical Industry Contracts Dept. (Luton 2440, Ext 84) for a quotation. Literature describing other KENT electronic equipment, such as amplifiers, servo motors, synchronous converters, is yours for the asking.

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PLANT EQUIPMENT NEWS

in bronze or stainless steel, as a bourdon tube or bellows, covers pressures from full vacuum to 10,000 psi. **Crosby Valve & Engineering Co. Ltd., Ealing Road, Wembley, Middx.**

BCE 4541 for further information

HANDLING EQUIPMENT

Aluminium Nozzle

A jerrican pourer in cast aluminium, designed to fit the claw-type neck of a 4½-gal. standard jerrican, is being made by **J. E. Lesser & Sons Ltd., Green Lane, Hounslow.**

BCE 4542 for further information

Dispensing Silos

Portasilo Ltd. have introduced an 11-ton dispensing silo which, although designed primarily for use with cement, is applicable to other powdered or granular materials. It is of laminated wood construction, phenolic resin bonded. Their larger model can now be fitted with automatic weighing equipment. **Portasilo Ltd., Coronation Road, Park Royal, London, N.W.10.**

BCE 4543 for further information

A portable silo made in resin-bonded plywood internally and fitted with an automatic weighing device has passed the prototype stage at the factory of **Acrow (Engineers) Ltd., Sour Wharf, London, W.2.**

BCE 4544 for further information

Drum Lifter and Up-ender

A device for lifting and up-ending drums is being made by Service Engineering Co. The capacity of the standard machine is 5 cwt. and this equipment is powered by a 2½-hp Brooks motor, the power being transmitted by hydraulic rams. The dimensions, as well as capacity, can be adjusted to suit the user. The drum is held in position by a specially-designed clamp as standard, but side-toggles can be provided as an alternative. The machine can be built and is controlled from a panel situated conveniently on the side. **Service Engineering Co. Ltd., Weedon Road, Northampton.**

BCE 4545 for further information

Drum-pouring Trucks

A new range of Jacacaddy trucks with squeeze clamps introduced by W. Langley have been designed for lifting drums over vats and pouring their contents at a controlled rate. The standard model will lift drums weighing up to 5 cwt. to a maximum height of 6 ft 6 in. and turns them through 180° at any intermediate height. The models can be adapted to take drums of up to 10 cwt. and to lift to a height of 10 ft. They may be operated by hand hydralically or by battery or mains power. **W. Langley & Co. Ltd., 14 Magdalen Street, London, S.E.1.**

BCE 4546 for further information

Light Barrel-skid

An aluminium alloy barrel-skid with runners fitted with wood battens and steel hooks is Powell's latest product. It is available in three standard lengths—8, 10 and 12 ft. **Powell & Co., Burry Port, Carms.**

BCE 4547 for further information

Rolling Conveyor

Dexion are marketing a new gravity conveyor consisting of slotted angle constructions, Glidewheels and punched strap. **Dexion Ltd., 67 Maygrove Road, London, N.W.6.**

BCE 4548 for further information

New Container for Chemicals

A new type of package, to be marketed in Britain at the beginning of 1959 by Iridon, one of the Commercial Plastics Group, the Cubitainer, consists of an outer corrugated cardboard cube supporting and protecting an internal, semi-rigid polythene container. Marked advantages are claimed for the product in the packaging, transport and storage of certain liquids, powders and semi-solids, when compared with drums, carboys, jars and canisters. Cubitainers will be available initially in five gallon, gallon and quart sizes. The containers are non-returnable. Before filling, they are delivered with the polythene insert collapsed and nested and the boxes folded flat, so that they occupy a minimum of warehouse space. The makers calculate, for example that 50,000 five-gallon Cubitainers collapsed occupy only 26,250 cu. ft against 84,000 cu. ft for an equal number of five-gallon glass containers. Also the containers are only one-fifth of the weight of glass containers. **Iridon Ltd., 1 Avery Row, Grosvenor Street, London, W.1.**

BCE 4549 for further information

MATERIALS AND COATINGS

Resin Hardeners

Recent development work on Leicester Lovell's range of hardeners has revealed a number of new advantages over polyamine hardeners, the company state. These include higher heat resistance in the room-temperature-cured epoxide resin, improved impact strength, less variation in gel time with change in temperature, less need for precision in measuring hardener in proportion to resin, and ability to act under damp conditions without significant loss of strength. **Leicester, Lovell & Co. Ltd., North Baddesley, Southampton.**

BCE 4550 for further information

Epinamel "EE"

A new interior-decoration coating. Epinamel "EE", suitable for chemical plants and other premises likely to be contaminated with corrosive chemical fumes is announced by **Arthur Holden & Sons Ltd., Bordesley Green Road, Birmingham, 9.**

BCE 4551 for further information

Stoneware Cement

In tests of the new corrosion-resistant cement for stoneware piping, Corro-Proof PXY, two 6-in. pipes were jointed in glazed condition with the cement with a fillet of NL natural-rubber latex cement, and pressure was at first applied to conform to the requirements of B.S.S. 1143/1955. The pressure then was increased, eventually to 100 psi, the maximum on the gauge, and neither the pipes nor joints showed any signs of leakage or failure, the producers report. **Corrosion Proof Products Ltd., Sunleys Island, Great West Road, Brentford.**

BCE 4552 for further information

Tankers' Corrosion Protection

Italy's largest and fastest motor tanker, the *Sicilmotor*, which entered service recently, is protected against corrosion in her cargo and ballast compartments by the Guardian multi-fin system of cathodic protection. **F. A. Hughes & Co. Ltd., 4 Stanhope Gate, London, W.1.**

BCE 4553 for further information

New Epoxy-based Coating

Corrosion Ltd. have introduced a new and improved heavy-duty epoxy-based plastic coating under the name of Epiglo type C. In field trials it has been used successfully, it is pointed out, on structures exposed to acid and alkaline fumes and as a lining in brewing, sewage, paper and photographic works. **Corrosion Ltd., 16 Gloucester Place, Portman Square, London, W.1.**

BCE 4554 for further information

NEW FOREIGN EQUIPMENT

Stronger Polyethylene Pipes

A polyethylene pipe with, it is said, up to nearly one-third greater initial burst strength than is obtainable with the existing pipe-grade plastic has been introduced by Union Carbide. The material, DHD-4022, has a density of 0.929 and a melt index of 1.0 to 1.5 and it has been approved by the National Sanitation Foundation of the U.S.A. for the transmission of drinking water. **Union Carbide International Co., 30 East 42nd Street, New York, 17, U.S.A.**

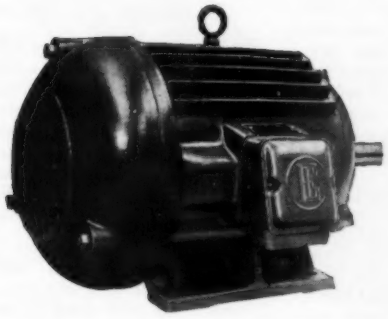
BCE 4555 for further information

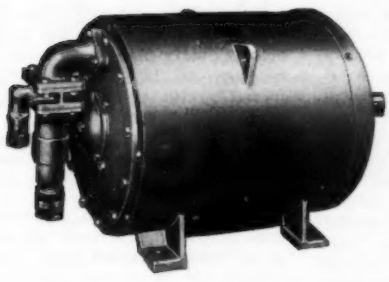
Pocket Calculator

A pocket slide-rule calculator for

BCE 4451 for further information

Motors for corrosive and explosive atmospheres





CHEMICALS & PAINT

Class 'LYC' motors to B.S. 2083 up to 25 h.p.
'ENGLISH ELECTRIC' is the only Company making chemical works motors to this standard. Tens of thousands of British Standard motors are in service. Available up to 50 h.p. in N.E.M.A. sizes.

Write for Publication DM/206

PETROLEUM

Class 'XLK' flameproof motors Squirrel-cage or Slipring. Totally-enclosed fan-cooled or Totally-enclosed. Complying with Oil Companies Materials Committee requirements. Buxton certified.

Write for Publication DM/154

COAL MINING

Class 'LP' steel-barrel, flameproof Squirrel-cage motors. Totally-enclosed fan-cooled available up to 150 h.p. Totally-enclosed available up to 50 h.p. Buxton certified for underground use.

Write for Publication DM/225

AVAILABLE FROM STOCK

'ENGLISH ELECTRIC'

industrial motors

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2.
Industrial Motor Works, Bradford
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

DM. 74

PLANT EQUIPMENT NEWS

determining the capacity and size of storage tanks up to 100 ft high and 300 ft in diameter has been newly marketed in the U.S.A. Capacities are given in U.S. gallons, barrels and pounds of water, and additional information includes decimal equivalents of a foot, equivalent volumetric units and steel plate weights for thicknesses $\frac{1}{16}$-1 in. **Hammond Iron Works, Warren, Pennsylvania.**

BCE 4556 for further information

Polyester Filter-plates

Filter plates in moulded polyester are being made by T. Shriver & Co., who point out that their advantage in weight saving is impressive. In an average 30-

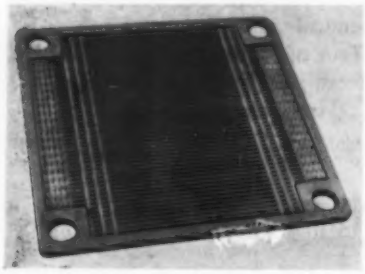


plate 36-in. press, the saving amounts to 2-3 tons over coated cast-iron (each plastic plate weighing 75 lb.). The plates' flexural strength is about 20,000 psi, the impact strength between 10 to 15 ft-lb./in. of notch and the recommended upper service temperature is 200 to 250°F. **T. Shriver & Co. Inc., Harrison, New Jersey, U.S.A.**

BCE 4557 for further information

Ceramic Honeycombs

Corning have introduced the Cercor process for forming thin-walled ceramics into lightweight honeycomb structures capable of resisting high temperatures. The low expansion at high temperatures and high surface area of the materials made by the process indicate that they have a wide use in heat exchangers and as catalyst supports and structural materials for high-temperature applications, Corning say. The structures can be built in a wide range of shapes and with a large number of ceramic compositions. **Corning Glass Works, 718 Fifth Avenue, New York, U.S.A.**

BCE 4558 for further information

Titanium Alloy

The new MST 881 titanium alloy (8%Al, 8%Zr, 1%Ta + Cb) developed by Mallory-Sharon has a maximum working temperature of 1100°F for long-time applications and of 1600°F for short-time applications, the manufacturers state. Satisfactory thermal stability under creep conditions is claimed, but welding tests have not been completed. **Mallory-Sharon Titanium Corp., Niles, Ohio, U.S.A.**

BCE 4559 for further information

New Publications

Continuous-cooling transformation diagrams are included for the first time in the new edition of the "Atlas of Isothermal-Transformation Diagrams of Nickel Steels" recently published by Mond Nickel. They cover the range of cooling rates involved in the oil-quenching of 1-in. to 6-in. diameter bars, and are intended to help to resolve the difficulties of practical application presented by isothermal data alone. The new edition, of some 91 pages, contains the isothermal diagrams and end-quench hardenability data given in previous editions. **The Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1.**

BCE 4560 for further information

Capacities at listed pressures and speeds are among the details supplied about Holmes-Connersville exhausters and boosters, type XAS, in Holmes' new publication No. 75. **W. C. Holmes & Co. Ltd., Turnbridge, Huddersfield.**

BCE 4561 for further information

An impact crusher for disintegrating rocks such as limestone and coal in outputs of up to 25 tons an hour is the subject of a leaflet recently published by **Veb Zementanlagenbau, Dessau, East Germany.**

BCE 4562 for further information

Recent publications dealing with the use of high-impact PVC include Bulletin No. G15 published by **British Geon Ltd., Devonshire House, Piccadilly, London, W.1**, which describes the product from the point of view of distribution of potable water. The booklet outlines the manufacture of high-impact polyvinyl chloride (Geon R.A. 170) and, in tables, compares its physical properties with those of other plastic materials used in pipe manufacture and outlines its chemical properties. Other aspects dealt with include flow properties, impact and tensile strength, installation and comparative costs.—Publication GT1 of **Chemidus Plastics Ltd., 26 Progress Way, Purley Way, Croydon, Surrey,** provides technical data on a number of plastics suitable for piping, including their latest addition to the rigid plastic pipe material, Chemidus HI-20.—Dimensions and prices of Polyorc B.H. high-impact rigid PVC tubing are stated in pamphlet PLAS/19A published by **Yorkshire Imperial Metals Ltd., P.O. Box 166, Leeds.** The company also offer a price list of fittings which, until they are manufactured in Britain, are being imported from George Fischer Ltd., Switzerland.—A list giving specifications of the pipes, valves and fittings in plastic, including Hipact PVC, which they are now making is available from **Extrudex Ltd., Western Road, Bracknell, Berks.**

BCE 4563 for further information

A handsomely-produced 17-page booklet has been issued by the Albright & Wilson Group to publicise the opportunities in the group for graduates in chemistry and chemical engineering. For chemical engineers openings occur in the research, central engineering and production departments and occasionally in sales, the company points out. The engineering department, it is pointed out, is responsible not only for plant maintenance, but for designing and fabricating much of the equipment used at the group's Whitehaven establishment. **Albright & Wilson Ltd., 1 Knightsbridge Green, London, S.W.1.**

BCE 4564 for further information

The use of telcothene, polythene processed by the Telegraph Construction & Maintenance Co., in pipes and tubing for the conveyance of cold water is the subject of an illustrated six-page pamphlet issued by **Telegraph Construction & Maintenance Co., Farnborough Works, Green Street, Farnborough, Kent.**

BCE 4565 for further information

An illustrated publication describing and giving specifications and detailed drawings of rolling shutters for buildings has been issued by **John Booth & Sons Ltd., Hulton Steelworks, Bolton.**

BCE 4566 for further information

A folder containing three introductory leaflets to Vinyl's polymer solutions, synthetic resins and synthetic resin emulsions, together with over twenty technical-data sheets, has been issued by **Vinyl Products Ltd., Butter Hill, Carshalton, Surrey.**

BCE 4567 for further information

The Fume-Gard head for controlling, with a high-velocity air-curtain, the fumes from pot melting furnaces is described in a leaflet available from **Air Control Installations Ltd., Ruislip, Middlesex.**

BCE 4568 for further information

Daniel Doncaster, one of the first companies to undertake the forging of titanium in Great Britain, have issued a brochure to indicate the amount of special skills needed and, indeed, developed by them for the forging of difficult materials. **Daniel Doncaster & Sons Ltd., Penistone Road, Sheffield, 6.**

BCE 4569 for further information

2,511 references to semi-conducting materials and transistors are contained in the recently-issued second edition of Newmarket Transistors' bibliography on solid state devices. It is twice as big as the first edition published four years ago. **Newmarket Transistors Ltd., Exning Road, Newmarket.**

BCE 4570 for further information

Rockweld have described their latest automatic arc-welding equipment and its uses in a brochure recently issued. **Rockweld Ltd., Commerce Way, Croydon, Surrey.**

BCE 4571 for further information

Hathernware Fibresin plastic laminates are the subject of a leaflet, FSN, recently issued by **Hathernware Ltd., Loughborough.**

BCE 4572 for further information

BCE 4452 for further information

CHEMICAL HOSE *SERVICE* —piping hot

MacLellan Hose Service gets you the right grade and size of Chemical Hose exactly where and when you want it.

In the London area the man who sees to that is the manager, Hector MacInnes, bagpipe virtuoso and MacLellan man for 15 years. Hector has played his pipes at Balmoral, in Germany and Italy, and occasionally even in Putney. He was Scottish Amateur Piping Champion in 1950 and once, at Hogmanay, he got a skirl out of a length of spiral bore.

Hector MacInnes knows chemical hose, suction and discharge, even better than his bagpipes. So does every MacLellan area manager and technical representative. There are qualities of "Hyheat" and "437" for acids, caustics and salts up to maximum concentration and temperature. Just say what you want.

With a background of over 80 years experience in the manufacture and treatment of rubber MacLellan are large enough to employ the most up-to-date methods and equipment; close-knit enough to give every order individual attention; adaptable enough to meet your special needs. Suction and discharge hose for chemicals, oil, water, sand, slurry, etc. Large stocks at all depots. Lengths generally up to 60 ft. Express delivery.

MacLellan HOSE

George MacLellan & Co. Ltd.

Makers of Rubber for Industry: suction and discharge hose, conveyor belting for outdoor and underground service, expansion joints, rubber jointing and cut joints, Macbond rubber and ebonite lining and covering, Mactex rubber buckets, roller and idler covers, asbestos millboard, protective clothing.

153-163 Shuna Street, Maryhill, Glasgow, N.W. Telephone: Maryhill 5111/9 Telegrams: 'CAOUTCHOUC' Glasgow.
London: Burston Road, Putney, S.W.15. Telephone: Putney 5678.
Belfast: 60b North Queen Street. Telephone: Belfast 22822
Newcastle: 3-5 Queen Street. Telephone: Newcastle: 27617

Month's News in Brief

I.A.E.A. Appoint Seven Scientists

The Board of Governors of the International Atomic Energy Agency has appointed seven eminent scientists to serve on the Agency's Scientific Advisory Committee. The seven members, nominated by Director-General **Sterling Cole** and appointed by the Board, are: **Prof. H. J. Bhabha** (India) (subject to the concurrence of the Government of India); **Sir John Cockcroft** (United Kingdom); **Prof. V. S. Emelyanov** (U.S.S.R.); **Prof. B. Goldschmidt** (France); **Prof. B. Gross** (Brazil); **Prof. W. B. Lewis** (Canada); and **Prof. I. I. Rabi** (U.S.A.).

The decision to establish a scientific advisory committee was taken by the Board of Governors on September 19, 1958. Its function is to provide the Board and the Director-General with advice on scientific and technical questions arising out of the Agency's programme submitted to it by the Director-General either on his own behalf or on behalf of the Board. The members are appointed in their personal capacity with the concurrence of their respective governments.

Norwegian Contract for Britain

Head Wrightson Stockton Forge Ltd., a subsidiary of Head Wrightson & Co. Ltd., have received an order from Titania A/S in Norway for the supply of a special-type Class H.18 rotary dryer 104 ft by 70 ft long. The dryer is to be used for the drying of ilmenite in a new titanium ore concentrates plant to be located at Telnes in South-west Norway. This new concentrate plant is being financed on an international basis. The contract was won in face of strong foreign competition.

New Simon-Carves Department

Simon-Carves Ltd. announce the establishment of a new department to build plants for complete gasification, gas reforming, ammonia synthesis and the production of nitrogenous fertilisers and certain types of petrochemicals. The department is under the management of A. J. Payne whose sales and projects organisation is situated at the London offices (28 Dover Street, S.W.1) of Simon-Carves. Contract work is dealt with at the Simon-Carves head offices at Cheadle Heath, Stockport.

Kuwait Gas Compressor Plant

In mid-1959 the Kuwait Oil Co. (in which BP has a 50% interest) states that they have plans to put into operation what will ultimately be one of the largest gas compression plants in the Middle East. The compressor, which will be driven by gas turbines, will compress gas to a high pressure so that it can be injected into the underground oil-bearing formation. This will reduce the amount of surplus gas which is now burnt at the field flares. Once the plant has been started up, it will control itself automatically and will shut itself down in case of any failure of the controls or other accident. After sufficient experience has been gained of the effect of operation of the first plant, it is planned to commission a second plant of equal capacity.

News Briefs

In our October, 1958, issue (p. 532) we announced that the Regional Advisory Councils for Further Education had issued new Bulletins and that details were available from the Local Education Authorities. This note was based on official information, but we have now been informed that the details are obtainable only direct from the Regional Advisory Councils themselves.

What is reported as the largest high-impact PVC tube ever produced in this country has recently been shipped to the Arab Potash Co., of Jordan, by Extrudex Ltd., Bracknell, Berks. The tubing measured 2565 ft, and was of 12-in. dia. ¼-in. wall feeder supply pipework in 'Hipact' in 30-ft lengths complete with eighteen 90-degree bends and ten 120-degree bends.

Seven 200-litre glass flasks—claimed to be the world's largest—are among equipment being supplied to Courtaulds Ltd., who have concluded a contract with Technopromimport of Moscow (see p. 526, September, 1958, issue), by Q.V.F. Ltd.

A new heat-treatment shop in the steel foundry of Edgar Allen & Co. Ltd. will treat austenitic (12-14%) manganese and other alloy steel castings, and operators employed in the shops are reported to have said that conditions are "much cleaner and the furnaces a lot easier to work".

The third intake into the sandwich course for the Diploma in Technology in Industrial Chemistry, held at the Northampton College of Advanced Technology, St. John Street, London, E.C.1, will be in February, 1959, followed by a fourth in September, 1959. Further details may be obtained from the Head of Department of Applied Chemistry of the College.

The 1959 programme for the Industrial Safety Training Centre operated by the Birmingham and District Industrial Safety Group may be obtained on application to 22 Summer Road, Acocks Green, Birmingham.

The Cheminform Institute, 10 Columbus Circle, New York, 19, New York, U.S.A., has just started a new chemical information service. A file of trademarks in the chemical and allied fields is now available for immediate use. A unique feature of this file is that it includes registered, unregistered, common, foreign, scientific and technological names in every type of chemical and chemical-using industry. In many cases, the chemical composition or active ingredients, use of the product and name of the manufacturer are given. It is international in scope, serving the most important foreign countries, in addition to the United States.

Sturtevant Engineering Co. Ltd. has created within its central organisation a cathodic protection department headed by Mr. J. H. Morgan, who has recently joined the company. All inquiries regarding cathodic protection should be addressed to the company's head office, Southern House, Cannon Street, London, E.C.4.

Evershed & Vignoles Ltd. have opened a district office at 14 Yarm Lane, Stockton-on-Tees. Tel.: Stockton 64288.

Aikman (London) Ltd.'s new address is 49 Egerton Gardens, London, S.W.3. Tel.: KNIghtsbridge 8731.

The address of Metropolitan-Vickers' London offices is now 33 Grosvenor Place, London, S.W.1. Tel.: BELgravia 7011.

Great Lakes Carbon International Ltd., with sales offices at 140 Park Lane, London, W.1, has been appointed sales representative for all commercial products of the new graphite plant of the Anglo Great Lakes Corporation Ltd. at Newcastle upon Tyne. In addition, the firm will also market graphite products of the Great Lakes Carbon Corp., U.S.A., throughout the United Kingdom and Western Europe. Charles H. Harrison, European sales director, and Cyril G. Conway, sales engineer, are conducting the firm's sales activities.

Ray-Heet (Infra-Red) Ltd. has recently become a member of the Vokes Group of Companies. It will trade under the new name of Ray-Heet (Process Plant) Ltd. with offices at Rayleigh House, High Street, Great Bookham, Surrey. Tel.: Bookham 3108.

Details of their 1959 training programme in work study, supervisory management and related subjects have been announced by the Engineering and Allied Employers' West of England Association, Engineers' House, The Promenade, Clifton Down, Bristol, 8, from whom further information can be obtained.

Wild-Barfield Electric Furnaces Ltd., of Watford, announce that the well-known NRC Type 912 vacuum fusion gas analyser for the determination of oxygen, nitrogen and hydrogen in metals is now available as a British-built unit. A demonstration equipment has been installed at the company's Elecfurn Works, Watford.

A. Gallenkamp & Co. Ltd. have been appointed sole United Kingdom agents for the range of continuous recording process instruments manufactured by Beckman Instruments Inc. These include their electrolytic hygrometer, *p*H meters, gas chromatographs, leak detectors, oxygen analysers and flow colorimeters.

The Incandescent Heat Co. Ltd., Smethwick, have established a Gas Atmospheres Division to co-ordinate design, development and sales of atmosphere generators, purifiers and gas driers. The new division is headed by Mr. I. L. S. Golding.

BCE 4453 for further information

For Distillation Columns...

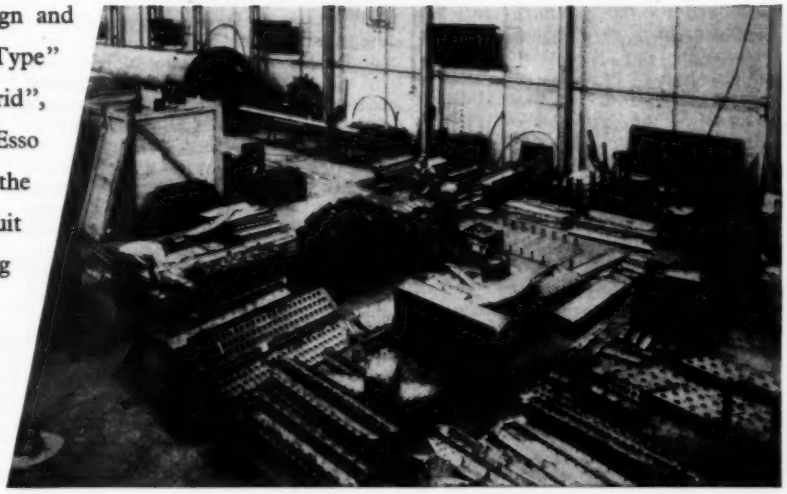
We manufacture both columns and internals to customer's designs or undertake the design and manufacture of complete distillation units from flow data.

The use of sectional tower internals enables us to offer strong but lightweight columns of one-piece, self-supporting construction. Four such stainless steel columns are shown here in course of construction in our works.

and Distillation Trays

We are licencees for the design and manufacture of Glitch "Truss-Type" bubble trays, Shell "Turbogrid", Socony Mobil "Uniflux" and Esso "Jet" trays, and can offer you the most suitable type of tray to suit your process and operating conditions.

Several different types of distillation tray components are shown here in course of inspection and packing.



Please ask for copy of our new 24-page brochure CP.58 "Serving the Oil and Chemical Industries".

Metal Propellers Ltd.

74 Purley Way, Croydon, Surrey. Telephone: THOrnton Heath 3611-5

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J. Brockhouse & Co. Ltd., in conjunction with W. G. Allen & Sons (Tipton) Ltd., announce that they are forming a joint company to be known as Brockhouse Allen Ltd., in the Federation of Rhodesia and Nyasaland.

Rhodes, Brydon & Youatt Ltd. have established new offices in Birmingham and Newcastle upon Tyne. The registered area offices addresses are Griffin House, Ludgate Hill, Birmingham, 3 (Tel.: CENtral 8911/2) under Mr. C. M. Saunders; and 60 Highbury, Jesmond, Newcastle upon Tyne, 2 (Tel.: 81-4722).

Flexibox Ltd., manufacturers of mechanical seals rotary shaft equipment, announce that they have appointed J. Turner & Co., 25 Collingwood Street, Newcastle upon Tyne, 1, as agents for the north-eastern area of Gt. Britain.

A.P.V.'s Chemical Engineering Division, which remained at Wandsworth, London, when the head offices and works of the company moved to Crawley, Sussex, has now also been moved to Manor Royal, Crawley, Sussex.

Opperman Gears Ltd., of Newbury, Berkshire, announce the transfer of their Northern Area office from Leeds to Manchester. The address is: 20 St. Ann's Square, Manchester, 2. Tel.: Blackfrairs 6451. Mr. M. G. Marsh is in charge of the Manchester office.

People in the News

Mr. D. F. Ward has recently been appointed to the board of Barlow-Whitney Ltd., of London and Bletchley. He joined the company in 1946 as technical buyer and for the last three years has been manager of the company's Neasden factory.

Mr. George Bradley, carbonisation general manager of the East Midlands Division of the National Coal Board, is to retire at the end of 1958.

Mr. G. C. R. Eley, C.B.E., has joined the board of The British Oxygen Co. Ltd.

Major-General E. P. Readman and **Miss V. A. Pease** have joined the board of Amber Chemical Industries Ltd. It has also been announced that **Mr. J. Firminger** has been appointed technical manager of the Amber Chemical Co. Ltd., and that **Mr. H. N. Wigan** has resigned from the board of that company.

Mr. G. L. Ball has been appointed general sales manager of Wayne Kerr Laboratories, Chessington, Surrey. He will be in charge of all the company's sales activities in this country and abroad.

In view of the substantial development since any appointment to the original board of directors of Wolf Electric Tools Ltd., the company felt it desirable, upon the recent retirement of **Mr. R. F. Hatto**, sales director, that the board be increased in numbers. The following members of the staff have been elected to the board: **Mr. N. McCann** (secretary and director); **Mr. R. G. J. Nisbet** (director of Canadian operations); **Mr. J. A. Jackson** (works director); and **Mr. W. N. Scottorn** (sales director).

Major C. J. P. Ball has retired from the boards of British Resin Products Ltd., Distrene Ltd. and British Geon Ltd., the three companies which form the Distillers Plastics Group. **Mr. T. F. A. Board**, a director of Distillers, has been appointed chairman of British Geon and of Distrene. **Mr. H. H. Woolveridge**, who is chairman of the Distillers Plastics Group, has been elected chairman of British Resin Products and **Mr. P. A. Delafield**, who is managing director of the same Group, becomes managing director of British Resin Products.

Mr. G. F. Dutton has been appointed deputy managing director of Project Constructors Ltd., Audenshaw, Manchester. Mr. Dutton's initial training and experience were gained in the shops and drawing office of G. A. Harvey & Co. Ltd., of London, followed by periods as draughtsman and, later, engineer with Fraser & Fraser & Co. Ltd. Afterwards he was assistant works manager with Brown & Tawse Ltd. During the war he was commissioned in R.E.M.E., and on his return to civil life he joined the Distillers Co. Ltd., with whom he spent six years initially as drawing office manager, but for the major part as a project manager. Following this, until he joined P.C. Ltd., he was chief engineer of Petrochemicals Ltd.

D. F. Wishart, who has been chief project engineer of the Chemical Division of Stone & Webster Engineering Corp. in Boston, U.S.A., has been named engineering manager of Stone & Webster Engineering N.V., recently-formed subsidiary in the Netherlands.

W. Kenneth Davis, vice-president of the Bechtel Corp., San Francisco, and former director of reactor development for the U.S. Atomic Energy Commission, has been named winner of the American Institute of Chemical Engineers' Professional Progress Award in Chemical Engineering. The Award was conferred on Mr. Davis during the 51st Annual Meeting of A.I.Ch.E. at Cincinnati, Ohio, on December 8. Mr. Davis was honoured "for his leadership in the engineering developments of nuclear power". He is the eleventh winner of the Award, which is given in recognition of outstanding progress in the field of chemical engineering.

Another recipient who was presented with his award at the same venue is **Dr. R. L. Pigford**, who has won the William H. Walker Award in recognition of distinguished contributions to chemical engineering literature, especially for his articles on rate processes. Dr. Pigford is the twentieth recipient of the Award, which is given annually to "encourage excellence in contributions to chemical engineering literature". He is a co-author of two books on chemical engineering and is a contributor to the "Chemical Engineering Handbook", and has also written articles on applied mathematics and unit operations in numerous publications.

Mervyn Instruments, of Woking, Surrey, have enlarged their marketing organisation by the appointment of the following: **Mr. V. M. Farrant** as sales promotion manager; **Mr. P. M. Bartlett** as divisional sales manager; and **Mr. J. A. Shelton** and **Mr. A. E. Deslandes** as technical liaison officers.

Obituaries

The death is announced, after a short illness, of **Mr. Frank R. Stagg**, deputy chairman of Thos. W. Ward Ltd., Albion Works, Sheffield. He joined the company in 1895 as an office boy and was appointed a director in 1927. In 1938 he was made assistant managing director and became deputy chairman in 1950.

The sudden death, on November 4, of **Mr. A. S. Dodds**, director and London manager of John Thompson Water Tube Boilers has been announced. He joined the company seven years ago and was appointed manager of the company's London offices in 1957.

Mr. E. G. Pickering, a joint managing director of Johnson, Matthey & Co. Ltd., died recently after a prolonged illness.

Meetings of the Month

Society of Chemical Industry

January 13. *Chemical Engineering Group:* At the Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. "An Organisation for Inspection", by E. W. Greensmith. **6.0 p.m.**

The Society of Instrument Technology

January 14. *Data Processing Section:* At Manson House, Portland Place, London, W.1. "Symposium on Storage Media". **5.30 p.m.**

January 27. At Manson House, Portland Place, London, W.1. "Symposium on Flow Measurement". **5.30 p.m.**

January 2. *Fawley Section:* At Copthorne House, Fawley, Hants. "Instrumentation of the Dounreay Reactor", by K. R. Sandiford.

January 9. *Midland Section:* At Regent House, St. Phillips Place, Colmore Row, Birmingham, 3. "Pilot Plant Instrumentation", by M. F. Binney. **7.0 p.m.**

The Institute of Refrigeration

January 8. At the Institute of Marine Engineers, The Memorial Building, 76 Mark Lane, London, E.C.3. "An Economic Evaluation of Large Ammonia Absorption Refrigerating Machines", by G. G. Haselden. **5.30 p.m.**

Institute of Metals

January 15. At 17 Belgrave Square, London, S.W.1. "The Oxidation of Metals at High Temperatures", by Dr. C. E. Birchenall. **6.30 p.m.**

Coming Events

January 19-22. At the Royal Horticultural Society's Old and New Halls, off Victoria Street, Westminster, S.W.1. Physical Society Annual Exhibition of Scientific Instruments and Apparatus.

January 13-15. At the Reading Office of N.I.F.E.S., Ailsa House, Kings Road, Reading. A Three-day Course on Fuel-oil firing.